AMERICAN JOURNAL OF OPTOMETRY
and ARCHIVES *of*
AMERICAN ACADEMY OF OPTOMETRY

Vol. 25 OCTOBER, 1948 No. 10

CONTACT LENS HAZE*

John Collins Neill†
Contact Lens Department
Pennsylvania State College of Optometry
Philadelphia, Pennsylvania

Today the design of contact lenses and their technique of fitting have been so improved that it is rather unusual to find a person who cannot be fitted comfortably with such lenses. Unquestionably much of the improvement dates from the adoption of plastic lenses with their lighter weight and greater adjustability. However, there still remains to be solved the problem of haze or fogging, a problem which has vexed the contact lens fitter from the very beginning. In some respects the problem has been aggravated rather than helped by the use of plastic lenses.

Haze or fogging of vision is a phenomenon experienced by nearly every wearer of contact lenses. The haze may be noticed immediately upon insertion of the lenses and then clear up and remain absent for a period of from one to many hours, or the haze may be present continuously from the moment of insertion or, as in most cases, the haze may be absent at first and not appear for from one to many hours after the lenses are inserted.

Contact lens haze for the purpose of our discussion will be divided into two categories: (A) Initial or Primary haze, that haze which is noticed immediately or shortly after insertion of the lenses and (B) Secondary haze, that which has its onset from one to many hours after insertion.

(A) PRIMARY HAZE

Primary haze is usually due to one or more of the following conditions: (1) Soiled lenses; (2) Improper centration; (3) Incorrect prescription; (4) Faulty wetting; (5) Contaminated solution; (6)

*Read before the annual meeting of the American Academy of Optometry, Chicago, December 15, 1947. For publication in the October, 1948, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Optometrist. Fellow, American Academy of Optometry. Chairman, Contact Lens Section, American Academy of Optometry.

Rotated lenses; and (7) Dynamic decentration. Most, if not all, of these conditions may be controlled by either the doctor or the patient after the cause of the haze has been determined.

(1) *Soiled lenses.* Lenses may be smeared with oil from the fingers before or during insertion, or they may be covered with a residue of salt if they were not dried properly after a previous use. Lenses should be washed carefully and should be handled only by the edges during insertion so as to prevent soiling of the lens surfaces. Occasionally, the anterior surface of the lens may be smeared during the process of insertion by contact against the lashes with their ever-present greasy meibomian secretion. Control of this problem will be discussed later under wetting problems.

We have recently seen two cases in which the patients complained of haze from the moment of insertion. Inspection of the lenses revealed that the anterior surface had a frosted appearance as though the polish had been destroyed by a chemical solvent or an abrasive. Further examination revealed that the surface was coated with a film which resisted the action of soap and water as well as that of the usual wetting agents. It was found possible to scratch this film with the fingernail. This fact gave us the clue which revealed that the lens was merely filmed over rather than etched. Further study of these cases showed that the film consisted of a dried exudate, probably a mucous secretion from the paraocular glands. The exudate was found to be soluble in naphtha and the patients were advised to clean their lenses regularly with this solvent.*

(2) *Improper centration.* This is one of the most common causes of primary haze. In addition to reporting a blur, the patient will also report that lines seem to radiate from the letters of the chart or that the letters look like Old English characters. One or both lenses may be decentered. Monocular vision in these cases may or may not be clear, but binocular vision is invariably blurred as a result of the prism created by the decentered lens or lenses. When the blur or radiating lines are noticed with either eye separately, it is sometimes found that a cylindrical prescription will improve the vision. This is not a case of true astigmia but a condition induced by faulty centration. It will disappear when the lens is centered.

Most contact lens fitters are in the habit of checking centration by marking a dot or a cross in the center of the corneal section of the lens, or by drawing a circle to outline the limbal ring. They then adjust the lens so that the mark or circle is centered on the wearer's eye. This seems

*It has recently been determined that ordinary table vinegar is an even more effective solvent for this type of film. A drop or two rubbed on the lens surface with the fingers will effectively remove the film.

to be a rather crude and inaccurate method when one considers that we are dealing with lenses of such power that even a fraction of a millimeter of decentration will produce several diopters of prismatic effect. The width of the mark used for indicating the center could of itself account for a great deal of prism. Furthermore, we have no way of knowing whether the optic axis of a particular eye is centered in either the pupil or in the limbal circle.

One of the easiest and at the same time most accurate methods of obtaining proper centration is for the doctor or the patient to move the lens while it is on the eye and while the patient is observing the smallest legible letters on the chart. The lens may be moved readily in any direction by light finger pressure through the lid or by pressure on the scleral rim with the handle end of a contact lens suction cup. The position of the lens which provides the clearest vision will invariably be the position of proper centration. The lens should be adjusted so that it will remain in this position. Care should be taken that both head and eye are in the primary position during this test.

(3) *Incorrect prescription.* It is rather rare today to find a contact lens with inaccurate prescription except through faulty refraction technique or through a mistake in transmitting the data to the laboratory. However, there are a number of factors to bear in mind in this regard. Major adjustments on the scleral rim may affect the depth of the water lens and thus create a refractive change. If care is not exercised in making thermal adjustments it is possible to warp the corneal section and thus introduce a cylindrical effect which will create false astigmatism. During the refraction through the trial contact lens, it sometimes happens that a ciliary spasm is present. This may be due either to irritation of the eye by the contact lens or to the fact that the patient has been made artificially hyperopic by the trial contact lens. In either case, there is danger of prescribing too little plus or too much minus correction. While the patient so corrected will seldom complain of blurred distance vision he will complain of difficulty with near vision. To insure sufficient plus power in the final prescription the refraction should be done with a slow careful fogging technique. A residual astigmatism may be found when the original refraction is being made through a trial contact lens. Tests should be made to determine whether this is a true astigmatism or one that has been induced by the contact lens itself. There are at least four possible causes for induced astigmia: (1) Trial lens not centered correctly; (2) Trial lens cocked at an angle; (3) Astigmia in the trial lens (this can be detected usually only by an examination of the lens surfaces on the keratometer); (4) Cone angle of a tangent cone type lens too steep thereby causing a deformation of the patient's cornea.

(4) *Faulty wetting.* Tears have a rather high surface tension against plastics and often fail to wet the surface of the contact lens adequately. This is particularly true with new lenses. However, wetting failure may occur with any lens which has been soiled by an oily film from the fingers or by the oily meibomian secretion. Failure of the corneal surfaces of a contact lens to be wetted with the tears will result in blurred vision. When a contact lens is not throroughly wetted the corneal surface of the lens presents a definite "lack-luster" appearance which is readily apparent to the trained observer.

Failure of a lens to become wet may occur immediately upon insertion of the lens or at any time thereafter. Intermittent wetting failure is seen with relative frequency. Obrig[1] has compared the failure of new lenses to become wet to a condition with which we are all familiar, namely; the case of a new steel penpoint which will not become covered with ink until after it is first moistened with saliva. Saliva in this instance, having a relatively low surface tension, serves as a wetting agent. While opposed to its use, saliva may also be used as a wetting agent for contact lenses, in which case the lens may be placed in the mouth and wetted all over or just moistened with the tongue so that the anterior surface alone is wetted. In either case, it is advisable for the patient to flush off the excess saliva with clear water before inserting the lens into the eye. It is also possible to wet the lens after it has been inserted by touching the corneal surface with the tip of a finger which has first been moistened with saliva from the tongue. While saliva is an ever-present and convenient wetting agent there are definite aesthetic and hygienic objections to its use.

There are many commercial wetting agents which are almost universally available. These generally do an efficient job of wetting. A two per cent solution of poly-vinyl alcohol in water is a wetting agent which has given good service in my practice. Most of the available wetting agents are rather irritating to the eye so that all but a thin film of these materials must be rinsed off with water before the lens may be inserted.

Phemerol is a proprietary product which is sold primarily as an ophthalmic antiseptic, but which also has marked wetting properties and is nonirritating to the eye. This product is marketed in one-pint bottles containing Phemerol (1:5000) in a two per cent aqueous solution of boric acid. The lenses may be immersed in Phemerol and then placed in the eye without rinsing. For cases of intermittent wetting failure, the lenses may be wetted while they are still being worn by the use of Phemerol in an eyecup. Schmidtke[2] has recommended that the patient keep his lenses in a small covered jar containing an ounce or so

of Phemerol when not wearing them. When the lenses are taken from the jar the excess solution should be removed by shaking and not by rinsing.

Methyl-cellulose is a product of high viscosity (4,000 centipose) which has been found to confer certain definite and desirable properties to the regular contact lens solution. Among these properties is the apparent ability to wet the contact lens and to keep it wet after insertion. Other properties of methyl-cellulose and the method of using this substance in contact lens solutions will be discussed later.

(5) *Contaminated solution.* Contact lens solutions sometimes are contaminated in the bottle with foreign material due to carelessness on the part of the patient. This can usually be avoided by instructing the patient to wash the bottle carefully before refilling it with fresh solution. We have seen instances where an old solution developed a fungus growth which gave it a cloudy appearance. Occasionally a contact lens solution is contaminated with oil from the lashes during insertion. The remedy here is to remove the lens and then reinsert it with a fresh clear solution.

(6) *Rotated lenses.* A rotated lens will cause a blurring of vision only when the rotation is of sufficient extent to cause the lens to become decentered. When a lens rotates to such a degree as to have the long temporal edge meet an anatomical obstruction such as the superior or inferior fornix, or in extreme cases when the temporal edge rotates through 180 degrees and strikes against the plica, the lens will be forced into a decentered position and will create haze as was described under improper centration. In some cases this decentration will occur only when the eye moves from the primary position. In this case the patient will report the haze as occurring only when he looks in a particular direction. The remedies here are obvious. The lens must be adjusted so as to prevent rotation; or, less desirably, the long temporal edge must be cut away so as to permit proper centration on all rotations.

(7) *Dynamic decentration.* A blur which occurs when the patient is looking in a direction away from the primary position is due to decentration. Such decentration may be due to dynamic lag, or it may be due to an anatomical obstruction to rotation. In the first instance, the lag must be reduced by adjusting the lens so as to increase scleral adhesion and in the second instance the lens contour must be reduced at the point of contact so that it will not meet the anatomical obstruction.

(B) SECONDARY HAZE

Secondary haze may be due to one or more of the following reasons: (1) Wetting failure; (2) Rotated lenses; (3) Cloudy solution; and (4) Oedema of the cornea.

(1) *Wetting failure.* While a contact lens may be perfectly wetted

when it is inserted, it is not unusual, as was mentioned previously, for it to stop being completely wetted at any time after insertion. This failure to remain properly wetted could be due to physiological changes in the surface tension of the tears, but it is more likely to be due to a smearing of the surface of the lens with meibomian secretion. In many persons wearing contact lenses there develops an excessive amount of secretion from the meibomian glands. This may happen as a result of undue stimulation of the glands by manipulation of the lids during insertion of the lenses or as a result of irritation set up by the lenses after insertion. To remedy this condition it is necessary either to remove the lenses and apply a wetting agent to them, or to use Phemerol in an eyecup while the lenses are still in place on the eyes.

Wetting problems are most prevalent among patients who have just begun to wear contact lenses, and seem to diminish in direct proportion to the length of time they have had the lenses. This, in all probability, is due to the fact that lenses wet better after the original polish has been worn off a bit and to the fact that the lids have become accustomed to them and gland secretion has returned to normal.

(2) *Rotated lenses.* As a rule, a contact lens will rotate only when the scleral fit is inaccurate. Such rotation will occur immediately or shortly after insertion. Occasionally a patient complains of blur only some time after the lenses have been inserted. Examination will reveal that the lens has become rotated. Generally such rotation will have been induced by the patient's rubbing of his lids laterally. If the lens is returned manually to its proper position the blur will disappear.

(3) *Cloudy solution.* Contact lens solutions frequently become cloudy after the lenses have been worn for some time. This cloudiness is caused by contamination of the fluid with oil or mucous from the para-ocular glands; i.e. the glands of Moll, Henle, Zeiss, Manz, Wolfring, Kraus and Meibom. The secretions of these glands are normally present in all eyes. They serve the purposes of lubricating the eyeball, preventing the tears from evaporating too rapidly from the cornea, preventing the tears from overflowing the lachrymal lake and of keeping the lashes bathed in oil. The quantity of these secretions normally present is so small that they will usually cloud the solution only after many hours of use, if at all. Sometimes, however, the manipulation of the lids incident to insertion of the lenses will stimulate the glands unduly and cause an excessive amount of secretion. The excess secretion may enter the water lens chamber by capillary action and cause a clouding of the solution.

When a contact lens is inaccurately fitted an irritation may be set up which will result in excessive secretion by the para-ocular glands.

If any edge of a contact lens is permitted to stand off from the sclera it is liable to rub against the palpebral conjunctiva with a scraping action. This will serve not only to set up an irritation with a resulting stimulation of the flow of mucous and oil but the edge which is standing off will provide a scoop-like action which will funnel the mucous and oil directly into the water lens chamber with a rapidity much greater than would be the case as a result of capillary action alone.

Contamination of the solution with either oil or mucous can be detected readily by macroscopic examination. When such contamination is seen the lens need only be removed and filled with fresh solution for clear vision to be restored. If the clouding occurs in a very short period of time irritation of some sort should be suspected and the cause sought for and eliminated.

(4) *Oedema of the Cornea.* When the blurred vision caused by the wearing of contact lenses clears up immediately upon removal of the lenses, it may be assumed that the cause lies with one or more of the conditions already discussed. When, however, the blur persists after the lenses have been removed we may be sure that the cause of the blur is a corneal oedema.

The transparency of the cornea is a result of its regular histological structure and the specific water balance of its cells. When this structure is disturbed and the cells, particularly of the epithelial layer, become oedematous, transparency is lost and vision becomes blurred. Because the oedematous cells have a diffraction effect upon light passing through them the patient will usually notice halos as well as a blurring of vision. This condition has been described by both Fick and Sattler and is frequently referred to as "Fick's Phenomenon" or "Sattler's Veil." The experience is not unique to contact lens wearers alone but is also shared by underwater swimmers and by persons suffering from glaucoma.

Early contact lens technicians were of the opinion that the corneal oedema experienced by nearly all contact lens wearers is due to an osmotic imbalance between the contact lens solution and the fluid of the epithelial cells of the cornea. In our early thinking we were inclined to consider the problem in the light of our laboratory experience with osmosis through semipermeable membranes in which an equilibrium is reached when the osmotic pressures on both sides of the membrane are equal. We reasoned that since the cornea did not become oedematous under normal conditions, although it is constantly bathed in tears, the osmotic pressure of the tears must be in equilibrium with that of the fluid within the cell. This led to measurements of the osmotic pressure of tears and efforts to obtain the same pressure in our contact lens solutions. In a few

cases the patient's own tears were collected and were used to form the water lens; but in spite of everything, the cornea still became oedematous.

After years of clinical experimentation with solutions of various osmotic pressures, all prepared with the thought of increasing the pressure of the solution to a point where the cells of the cornea would not imbibe water, it was finally realized that there must be certain additional factors introduced by the wearing of contact lenses which are not present normally.

The contents of a cell vary as a result of two processes, diffusion and osmosis. Nutrient materials are introduced and waste products are eliminated by the first process and changes in water content are accomplished by the second. These two processes are intimately connected. The amount and direction of osmosis or passage of fluid through a cell wall depends on the relative osmotic pressures of the solutions on the two sides of that wall. These osmotic pressures in turn depend on the nature and on the concentrations of the dissolved materials present in these solutions. Finally, the presence or absence of specific dissolved materials in the cell, and their concentrations if present, depend in large part on the permeability of the cell wall. This permeability varies with environmental conditions and with the age of the cell, so that we must finally conclude that the osmotic pressure of the cell contents is in a constant state of flux.

It is felt that the permeability of the epithelial cells of the cornea is of paramount importance in the development of corneal oedema and its attendant contact lens haze. The following factors must be considered as having a direct bearing on this permeability during the wearing of contact lenses: (A) Initial osmotic pressure balance; (B) Tissue respiration; (C) Circulatory interference; (D) Hydrogen ion concentration; (E) Irritation; and (F) Intra-ocular pressure balance.

(A) *Initial osmotic pressure balance.* If we could assume that the osmotic pressures of the tears and of the fluid of the epithelial cells of the cornea are normally in a state of equilibrium, then it would seem logical to suppose that, *if other factors could be controlled,* the osmotic pressure of the ideal contact lens solution should match that of the tears; i.e., it should be isotonic with a 1.1 to 1.4 per cent sodium chloride solution. Clinical experience with aniline dyes shows clearly that the original contact lens fluid is gradually diluted and eventually replaced with tears. Thus, if the osmotic pressures of the solution and of the tears were identical to begin with, the pressure should remain constant.

It has been shown that the osmotic pressure of tears is higher on the cornea than at the orifices of the lachrymal gland; this is because

water is evaporated from the tears as they pass over the cornea of the uncovered eye. When an eye is covered by a contact lens the tears do not evaporate and the osmotic pressure is lower than it would be normally.

If the initial contact lens solution was to any great extent hypotonic the cornea would imbibe water rapidly and produce a hazing effect in short order.

If the initial solution is hypertonic it would draw water from the cornea until an equilibrium is reached, or until the hypertonicity is reduced by dilution with tears. Some patients have been able to increase their wearing time by changing the solution at intervals using progressively increased concentrations; each change would withdraw fluid from the cornea and would reduce the blur temporarily. Unfortunately solutions which are hypertonic cause a severe stinging and smarting sensation which is intolerable to most patients.

A few patients have been able to reduce corneal oedema to the point of eliminating the haze, by removing their lenses and bathing the eyes for several minutes with a 10 per cent solution of sodium chloride used in an eyecup. This solution also produces considerable stinging and smarting and is, therefore, not suitable for most patients.

(B) *Tissue respiration.* Duke-Elder[3] and others assume that the cornea, to compensate for the absence of blood, possesses a respiratory mechanism by which oxygen and carbon dioxide are transpired through the epithelium and endothelium. They believe, on the basis of experimentation with animals, that oxygen and carbon dioxide have the ability to pass through the cornea in only one direction, oxygen passing through the epithelium from the surrounding air towards the anterior chamber and the carbon dioxide passing forward through the cornea towards the atmosphere.

Bullot[4], on the basis of experiments on rabbits' eyes, believes the endothelium needs oxygen to maintain its transparency. Fischer[5], working with luxated eyes of rabbits, interprets the results of his experiments as indicating that interference with the normal passage of carbon dioxide through the cornea to the surrounding atmosphere leads to a loss of transparency of the cornea. Anderson[6] mentions experiments in which corneal clouding was produced by covering the eye with an air-tight cup and then passing carbon dioxide across the cornea using an atmosphere of nitrogen as the carrier.

Bakker[7] feels that our present knowledge of corneal respiration is rather defective and that the experiments of Bullot and Fischer were carried out under circumstances which were so far from being physiologically normal that the results are valueless. Bakker's own experiments were carried out on living white rats under conditions as nearly physio-

logical as possible. He determined that in an atmosphere of pure carbon dioxide the cornea becomes opaque in a matter of half an hour, but that in a concentration of eight per cent (which is higher than any normal carbon dioxide concentration in the body) the cornea does not suffer any changes over a period of many hours.

According to Anderson, while there are wide differences in individual patients, the increase of carbon dioxide in a contact lens solution during use averages about 0.005 of a cubic centimeter per hour. Anderson admits that this is a small quantity but points out that it assumes considerable proportions in comparison to the small volume of solution in the average contact lens. Bakker says that the clouding of the cornea in an atmosphere of pure carbon dioxide is a toxic effect produced by the gas in concentrated form, an effect which he was unable to produce with lesser concentrations. It would seem then that corneal clouding does not occur in low or moderate concentrations of carbon dioxide and that in high concentrations the effect is toxic. Both causes may operate but we do not know at what concentration of carbon dioxide the clouding effect begins and at what concentration the toxic action starts.

In the separate experiments cited by Bakker and Anderson the eye was exposed to carbon dioxide in an air-tight chamber in which it was possible to raise the carbon dioxide pressure to a point above that of the eye. A contact lens fitted to the eye does not normally constitute an air-tight chamber in this same sense. Fluids can and do enter and leave this chamber. Fluids, and especially the buffered solutions used in contact lenses, absorb carbon dioxide. It is to be expected that the fluid escaping constantly from the contact lens chamber would carry away and dissipate some of the carbon dioxide given off by the cornea.

Most writers who have discussed the problem of carbon dioxide-oxygen respiration of the cornea in the case of contact lens wearers have assumed that the plastic contact lens acts as a complete barrier to such respiration. Goodlaw[8] suggested that contact lens manufacturers "endeavor to make their lenses of some semipervious material to allow for the oxygen-carbon dioxide exchange" and Anderson[9] has suggested that "eventually the problem may be solved by making contact lenses in such a manner that the limbal area will be of a material that would be permeable to the carbon dioxide and yet retain the solution." Apparently it is not generally understood that the methyl methacrylates of which modern contact lenses are made are themselves colloidal substances. Therefore, they serve as semipermeable membranes and allow osmosis and diffusion to take place. While the rate of diffusion is slow, because of the thickness of the material, some osmosis and some diffusion must occur.

The carbon dioxide pressure of the atmosphere is equal to 2.8 mm. of mercury. The blood and cells of the cornea must contain sufficient carbon dioxide to equalize this pressure. When the pressure of carbon dioxide in the tissues is greater than 2.8 mm. the carbon dioxide is "exhaled." If the pressure of carbon dioxide in the water lens chamber were to increase above that of the atmosphere, it seems logical to suppose that the excess would either pass through the lens by diffusion, or, as we previously suggested, pass out of the chamber with the escaping fluid. In any event it does not seem probable that clouding of the cornea could be attributed *directly* to the relatively small amount of carbon dioxide which is retained in the water lens chamber.

(C) *Circulatory Interference.* In order to serve as an optical medium, the cornea must possess an avascular structure. It receives its nourishment by a process of diffusion almost entirely from the superficial marginal plexus in the region of the limbus and to a lesser extent from the fluid in the anterior chamber. Diffusion from either source occurs from the periphery of the cornea towards the center. The endothelium normally prevents both diffusion and osmosis from the anterior chamber directly into the cornea. Even when the hydrostatic intra-ocular pressure is increased to as much as 200 mm. of mercury the endothelium prevents the passage of water. However, increases in the intra-ocular pressure do result in a more rapid diffusion from the periphery.

While the metabolism of the cornea is extremely slow it has been demonstrated that when the circulation is interrupted for a length of time the cornea loses its transparency. It is evident then that pressure exerted upon the limbal plexus by a contact lens could interfere with circulation to the cornea and thereby result in corneal clouding. It is also conceivable that pressure on the sclera near the limbus could be transmitted to the limbal region with the same result. We have all seen cases where a re-designing of a contact lens, so as to afford better limbal clearance has resulted in longer haze-free wearing time.

There have been many reports of longer-than-average wearing time experienced by patients who were fitted with lenses which rested on the apex of the cornea and did not use a contact lens solution. The thought occurs that such wearing time may have resulted from freeing the limbal plexus of pressure rather than from the absence of solution or the freedom of tissue respiration as has been suggested.

Up to this time contact lens pressure has been thought of mostly as a direct physical pressure resulting from the lens in contact with the sclera. Many contact lens fitters have expressed private opinion that if there is any hydraulic pressure in the water lens chamber it is of negative nature. In an effort to clear up this question, Lewis and Neill[10] have

undertaken an experiment in which a manometer is connected directly to the water lens chamber through an opening in the corneal section of a contact lens while it is in place on a subject's eye. At this date, a sufficient number of readings have not been made to prove the point completely but those which have been made definitely indicate a positive pressure. If further readings verify the preliminary findings, then we must conclude that we are dealing not only with physical pressure upon the sclera but also with hydrostatic pressure upon the cornea and limbus. Such pressure could cause clouding as a result of interference with circulation and resultant metabolic activity. This pressure would also alter the osmotic pressure of the water lens so as to force water into the cells of the cornea.

Dallos[11] and others have experimented with lenses which rest upon the sclera in the usual manner but which have fenestrations around the scleral portion or holes in the corneal section so as to permit of a free interchange of solution and tears. Such lenses are claimed to afford longer wearing time. If this is the case, then the probable explanation is that such lenses permit no hydrostatic pressure to be exerted upon the cornea and limbus and do not alter the osmotic pressure of the fluid lens.

Hydrogen ion concentration. For many years it was felt by contact lens fitters that the hydrogen ion concentration of a contact lens solution is equally as important as the osmotic pressure value in determining the blur-free wearing time of contact lenses. During that period, it was customary to determine the pH value of each patient's tears by the use of an indicator such as "Hydrion" paper and to match the pH of the contact lens solution to that of the tears. Clinical experience soon proved that a contact lens solution with a pH higher than that of the tears was tolerated to a better degree than one which matched them exactly. In our experience the pH values of solutions have little or no effect upon corneal oedema except insofar as they do or do not produce conjunctival irritation. Solutions with a pH value between 8.0 and 8.5 seem to be tolerated to the best degree. Solutions with a pH value above 9.0 usually irritate the conjunctiva and cause an immediate burning sensation with excessive lachrymation and hyperemia. Likewise, solutions which have a pH between 7.5 and 7.0 are likely to produce irritation, but the degree of irritation is less than with those having a pH above 9.0. Finally, solutions having a pH below 7.0 are generally intolerable.

Today, contact lens fitters are generally prescribing solutions of sodium bicarbonate varying in concentration between one and two per cent. They usually prefer about 1.5 per cent. While such solutions have no direct control over the development of a corneal oedema, they are usually quite comfortable to the average contact lens wearer. In

some instances the addition of a small quantity of sodium chloride to the sodium bicarbonate solution will prolong the blur-free wearing time. The added sodium chloride produces no irritation and probably benefits the wearing time by increasing the osmotic pressure of the solution.

Contact lens solutions which contain one and one-half per cent bicarbonate have a pH of approximately 8.45. Determinations of the pH of the solution remaining in a contact lens after it has been worn for a period varying from one to several hours show that there is considerable drop in the pH, often to as low as 7.0 or thereabouts. Others have sought to explain this drop on the basis of the absorption of the carbon dioxide expired by the cornea. In our opinion, the lowering of the pH is the result of the loss of the original solution and its replacement by tears which normally have a pH between 7.2 and 7.4. The fact that the remaining solution has a pH below that of the tears can be accounted for by the addition of the metabolic end products which are of an acid nature.

Contact lens solutions which contain sodium bicarbonate are not stable. Owing to the loss of carbon dioxide the bicarbonate is gradually changed over to carbonate which has a much higher pH and therefore becomes quite irritating to the eye. The loss of carbon dioxide is accelerated by heat and retarded by cold. (Commercially, sodium carbonate is produced from sodium bicarbonate by being heated in open containers.) This brings out two important considerations for the contact lens technician: first, solutions of sodium bicarbonate should be freshly prepared and second, these solutions should not be heated.

Lewis and Rubinsohn[12] have made accurate determinations of the effect of time and temperature upon the stability of solutions of sodium bicarbonate. They found that when two solutions of sodium bicarbonate with an initial pH of 7.9 were kept in closed containers, one at room temperature and the other at body temperature, the pH of the first increased to 8.5 and that of the second to 8.6 in a period of three hours. At the end of three days the pH of these solutions had risen to 8.6 and 8.7 respectively.

In order to insure that our patients will always use a fresh solution, we do not prescribe or dispense the sodium bicarbonate in the form of a solution. Instead we provide our patients with gelatin capsules each one filled with 6.75 grains of sodium bicarbonate. The contents of one of these capsules dissolved in one ounce of distilled water provides a one and one-half per cent solution. Weaker or stronger solutions may be prepared by using more or less water. Patients are instructed to make a fresh solution at least every third day in cold weather and more frequently in hot weather. Ordinary distilled water is used as the solvent.

Warming of the solution used in the office is avoided because of the rapid increase in the pH which such warming produces.

Berenholtz[13] and others have pointed out that although the pH of freshly-distilled water should be 7.0 theoretically, that due to the absorption of carbon dioxide from the atmosphere, most commercially available distilled water has a pH which is much lower than 7.0 They have suggested that for this reason double or triple distilled water should be used for making contact lens solutions. We are at a loss to understand this reasoning for regardless of how many times water is distilled, as soon as it is exposed to the atmosphere it begins to absorb carbon dioxide and the pH begins to drop below 7.0.

We have compared the pH values of two sodium bicarbonate solutions each one and one-half per cent in strength. One solution was made from freshly-distilled water having an original pH of 6.75 and the other was made from distilled water which had been freed of carbon dioxide by boiling to yield an original pH of 6.95. The difference in pH of the two final solutions was only 0.05 of a unit. Clinically we consider this difference to be insignificant and therefore, can see no reason for putting our patients to the inconvenience and expense of purchasing specially prepared distilled water. If for any reason it is desirable to free ordinary distilled water of carbon dioxide, this may be accomplished by boiling the distilled water.

A few of our patients who reside in areas where the tap water is unusually pure and so requires but little chlorination have reported good results with solutions made from such water after it had been boiled. However, we do not ordinarily recommend the use of tap water.

As was mentioned previously in this paper, methyl cellulose (Dow Methocel), one-third of one per cent, added to the one and one-half per cent sodium bicarbonate solution, has proved helpful in many cases. Methyl cellulose (4,000 centipose) is highly viscous even in low concentrations. It resists dilution with the tears for a much longer period of time than do ordinary solutions, probably because its viscosity retards seepage from the water lens chamber. As a result of the retention of the original solution in the water lens chamber, the pH of the contact lens solution remains constant for a longer period of time.

In addition to the foregoing benefit as a result of its high viscosity, and the benefits resulting from its ability to "wet" the plastic contact lens as discussed in another part of this paper, methyl cellulose seems to provide better lubrication for the action of the lids. It also has a tendency to seal off tiny leaks which might otherwise result in pin-point bubbles. Some patients have reported longer blur-free wearing time when using methyl cellulose solutions. We believe this to be due to

the fact that there is less irritation of the conjunctiva when the contact lens is well "wetted" and well lubricated and the solution itself is able to maintain a more constant pH value.

(E) *Irritation.* It is generally agreed today that when an irritation of the conjunctiva is produced by a contact lens or by a contact lens solution that a corneal oedema will result earlier than might otherwise be expected. It is interesting to note here that this opinion is a reversal of the view held in the early nineteen-thirties when Zeiss lenses were being fitted. Our ideas on the subject at that time were succinctly expressed by Dallos[11a] when he stated, "more irritation—less veil, less irritation—more veil." Our failure to appreciate the effects of irritation was probably due to the fact that lenses which irritated beyond the point of ready toleration were not allowed to remain on the eye long enough to produce a corneal oedema.

We know now that an early oedema of the cornea may be expected whenever an irritation is set up in conjunction with the wearing of contact lenses. Such irritation may be produced by a clumsy insertion of the lenses, or by the inclusion of eyelashes or foreign material of any sort, or by contamination with tobacco oil or nail polish from the fingers. An improper pH or an improper osmotic pressure of the contact lens solution will also cause an irritation. Likewise, mechanical difficulties such as lens edges which stand off from the sclera or outside joints which rub against the palpebral conjunctiva, or inside joints which strike the limbus will all produce their measure of irritation.

Irritation of the tissues by physical, chemical or pathological stimuli in any part of the body always results in a condition of hyperemia and an increase in capillary permeability with consequent oedema of the part. The eye is no exception to this rule. When the conjunctiva is irritated by any of the stimuli mentioned above, a hyperemia is produced with a loss of fluid from the capillaries to the surrounding tissues. In the case of the cornea the fluids escape by way of the capillaries in the limbal plexus and then spread through the cornea from the periphery toward the center by osmosis, or by imbibition, or by a combination of these two processes. It has been noticed that hazing of the corneal epithelium always commences at the periphery and spreads gradually toward the center of the cornea.

According to Dallos[11b], F. A. Williamson-Noble has conducted experiments in which he blocked the facial nerve by the injection of proctocaine and in this manner succeeded in preventing veiling or hazing. Blocking of the facial nerve prevents the transmission of sensory stimuli such as would normally be set up by irritation of the conjunctiva. It is logical to conclude from this fact that irritation is an important factor in the production of corneal oedema.

A contact lens designed to minimize conjunctival irritation should have smooth edges, also, it should have surfaces which are tangential to the sclera so as to avoid rubbing of the palpebral conjunctiva. Within anatomical limits, the contour of the lens should be large enough to prevent the edges of the lens from coming into contact with the lid margins either in the process of blinking or in the act of rotation. The joint at the corneal-scleral junction on the anterior surface of the lens should be smooth and transitional in nature so that the lids will ride freely over the joint. The joint on the posterior surface should also be smooth and transitional in nature so as to prevent bumping of the limbus on rotation as well as to prevent physical pressure on the aqueous veins originating in the limbus.

Contact lens solutions should be adjusted to a pH and to an osmotic pressure which will not cause chemical irritation. In addition such solution should contain an agent which will help to keep the lens properly "wetted" and also afford lubrication to the lids.

(F) *Intra-ocular Pressure Balance.* Up to this point we have limited our discussion of the problem of corneal oedema to factors which operate from without the eye. Now let us examine the possibility of a change in the delicate intra-ocular fluid balance as a causative factor in corneal oedema.

Obrig[14] states that he has taken tonometer readings both before contact lenses were worn and again after clouding of the epithelium had occurred as a result of wearing the lenses. He reports that in no case was there any indication of a change in intra-ocular pressure. While there is no doubt of the validity of Obrig's statement it should be emphasized that the tonometer is not an instrument of accuracy in recording an absolute measure of intra-ocular pressure. The tonometer actually measures the total tension of the cornea, and while it is true that this tension is due in most part to intra-ocular pressure, the tonometer reading is not identical with this pressure nor does it vary directly with it. Furthermore, the instrument is not sufficiently accurate to record minute changes in intra-ocular pressure. Then too, since readings must of necessity be taken several hours apart, an error creeps in as a result of the fact that the intra-ocular pressure varies according to diurnal influences during the day.

It was mentioned previously in this paper that corneal oedema is not unique to contact lens wearers alone, that the same phenomenon is experienced by underwater swimmers and by persons having glaucoma. In all of these instances there is the factor of pressure. The contact lens wearer experiences mechanical pressure upon the sclera as well as hydrostatic pressure upon the cornea and the limbus. The glaucomatous

patient suffers increased intra-ocular pressure which is believed to be caused by some interference with the aqueous drainage system, while the swimmer under water suffers a pressure upon his eyes equal to the weight of the column of water above him.

At this time we would like to direct attention to the investigations conducted by Ascher[15] and would like to propose a hypothesis based upon his findings. In 1942, Ascher reported that he had proved the existence of what he terms aqueous veins. Using a corneal microscope with illumination provided by the modified Gullstrand slit-lamp of the Bausch and Lomb unit, he was able to see and to trace structures which resemble blood vessels. These structures contain highly diluted blood, or a fluid clear as water. They lead from the limbus or the para-limbal region toward the equator of the eye and finally empty into the conjunctival or episcleral vessels. After repeated investigations, Ascher has been able to show that these structures have to do with the elimination of intra-ocular fluid which is mixed in varying ratios with blood. He has demonstrated that these aqueous veins are biomicroscopically visible pathways extending from the canal of Schlemm to both the conjunctival and sub-conjunctival veins.

Ascher has studied the effect of pressure applied to the bulb with a cotton-tipped applicator and has shown clearly that such pressure produces an increase of red blood cells in the aqueous veins. Close observation indicates that the mere pressure of lid closure or of blinking is sufficient to cause a reversal of flow in the aqueous vein, or in its recipient vessel or in both of these structures. Further study of these veins following the instillation of various drugs produces equally startling results. When atropine and other mydriatic drugs are instilled there is an almost immediate reversal of flow as indicated by the presence of red blood cells in an aqueous vein which previously had been filled with clear aqueous material. This effect is observed before the pupil shows any dilatation. The instillation of eserine and other miotic drugs is followed immediately by an increase in the caliber of the aqueous veins and by an increase in the amount of outflowing fluid. This effect too, is observed before there is any noticeable constriction of the pupil.

Ascher has observed further, that any congestion of the conjunctiva whether caused by chemical or physical irritation is sufficient to cause a reversal of flow with the appearance of red blood cells in the aqueous veins.

In view of Ascher's findings it does not seem unreasonable to assume that here we have a logical explanation for contact lens corneal oedema. If the mere pressure occasioned by the closure of the lids is sufficient to cause a reversal of flow in the aqueous veins, then the

pressure, physical or hydrostatic, of a contact lens on the sclera or limbus should be sufficient to produce the same result. Here also lies the possible explanation of the fact that lenses which are constructed so as to rest on the cornea and thus free the limbus and para-limbal regions of pressure, do not cause corneal hazing. Fenestrated lenses and lenses with holes in the corneal section would also free the limbal region of hydrostatic pressure and would not interfere with aqueous flow. These, therefore, might be worn without producing a corneal oedema. On this basis, we must continue our investigations of the use and fitting of lenses designed to eliminate hydrostatic pressure on the limbal and para-limbal regions.

Ascher has also demonstrated that conjunctival irritation, whether caused by mechanical or physical irritants or by pathological processes, will result in a constriction of the aqueous veins with a reversal in the direction of their flow. This tends to strengthen still further our hypothesis, since we have all seen cases where an improperly adjusted contact lens which causes conjunctival or limbal irritation will show a corneal oedema much sooner than will a properly adjusted lens which consequently causes no irritation.

SUMMARIZATION:

Two types of corneal hazing as the result of wearing contact lenses have been discussed: Namely, Primary Hazing which is defined as the hazing which disappears when the lenses are removed; and Secondary Hazing which is defined as the hazing which persists even after the lenses which caused the hazing are removed from the eyes.

Under the title of primary hazing the following causes have been listed and discussed: (1) soiled lenses; (2) improper centration; (3) incorrect prescription; (4) faulty wetting; (5) contaminated solution; (6) rotated lenses; and (7) dynamic decentration. Suggestions have been given for the control of these causes by either the doctor or the patient.

As possible causes of secondary hazing we have listed and discussed: (1) wetting failure; (2) rotated lenses; (3) cloudy solution; and (4) oedema of the cornea. Under the heading of oedema of the cornea we have listed the possible causes as: (A) initial osmotic pressure balance; (B) tissue respiration; (C) circulatory interference; (D) hydrogen ion concentration; (E) irritation; and (F) intra-ocular pressure balance.

Experiments have been cited which tend to support the following theories: (a) that corneal hazing is not directly due to the osmotic pressure of the initial solution; (b) that corneal hazing cannot be attributed directly to the retention of carbon dioxide by the cornea;

(c) that corneal oedema may be due to the obstruction of the aqueous veins which originate in the limbal region by hydrostatic pressure created by the contact lens; and (d) that corneal oedema may result from conjunctival irritation.

It is suggested that experiments should be continued with lenses which relieve hydrostatic pressure upon the limbus and upon the paralimbal regions. It is also suggested that the design of contact lenses should be such as to provide adequate limbal clearance with joints which are smooth on both the anterior and posterior surfaces of the lens. The contour size should be as large as possible, within anatomical limits, so as to prevent the edges of the lens from rubbing against the lid margins and thereby setting up an irritation. Solutions and lenses which do not produce irritation are of paramount importance in our quest for the perfect contact lens

5128 NORTH BROAD STREET
PHILADELPHIA, PENNSYLVANIA

REFERENCES

1. Obrig, T. E.; Contact Lenses. 1st Edit. 1942. p. 264.
2. Schmidtke, R. L.; Am. J. of Ophth.; Vol. 30, 1947, p. 1013.
3. Duke-Elder, W. S.; Text Book of Ophth., Mosby, 1934, Vol. 1. p. 474.
4. Bullot, G.; J. of Phys., Vol. 31, 1904, p. 359.
5. Fischer, F. P.; Arch. f. Angenheilk.; Vol. 102, 1929, p. 146.
6. Anderson, A. L.; Precision Contacts Monthly Bulletin, Vol. 1, 1947, No. 9.
7. Bakker, A.; Br. J. of Opth., Vol. 31, 1947, p. 101.
8. Goodlaw, E. I.; Optom. Weekly, Nov., 1946, p. 1675.
9. Anderson, A. L.; Precision Contacts Monthly Bulletin, Vol. 1. 1947, No. 10.
10. Lewis, J. B. and Neill, J. C.; Unpublished data—Contact Lens Dept., Penn. State College of Optometry.
11. Dallos, J.; Br. J. of Ophth. Vol. 30, 1946, p. 607.
11a. Ibid.; p. 610.
11b. Ibid.; p. 611
12. Lewis, J. B. and Rubinsohn, L. B.; Unpublished data. Research Dept., S. H. Durst Co., Phila., Pa.
13. Berenholtz, H.; Opt. J. Rev. Optom., Oct. 15, 1947, p. 44.
14. Obrig, T. E.; Contact Lenses, 1st Edit. 1942, p. 338.
15. Ascher, K. W.; Am. J. Ophth., Vol. 25, 1942, pp. 31-38, pp. 1174-1209, pp. 1301-1315.

ABSTRACTS

ILLUMINATION STANDARDS, Miles A. Tinker, Lighting Review and Digest. 4. 2. 1-8. 1947.

Tinker finds that illuminating engineers, architects and electrical contractors are prone to specify relatively intense light without a proper scientific background of facts to support their suggestions. They ignore the psychological factors of seeing and frequently advise clients to install lighting equipment which provides many more foot candles of illumination at the working level than necessary.

Tinker also claims the blink-rate test, which has been used by some investigators in this field, is not a valid test and that the findings of experimental research in the psychological laboratories of the University of Minnesota show that from 10 to 50 foot candles of light at the working level is adequate for all tasks. C. C. K.

ACCOMMODATIVE CONVERGENCE IN IDENTICAL TWINS*

H. W. Hofstetter†
School of Optometry, The Ohio State University,
Columbus, Ohio

INTRODUCTION

Studies made on groups of twins are helpful in identifying the human traits that are dependent upon heredity. This follows from the assumption that traits which are inherited will show greater similarity between offspring of the same parents than between unrelated or distantly-related individuals.

According to Rife[1] there is now convincing evidence from biological and statistical data that *identical* twins consist of individuals who originated from the same fertilized egg cell or zygote, and that *fraternal* twins arise from two different eggs fertilized by different sperms. Hence the two types of twins are generally referred to as monozygotic and dizygotic, respectively. Fairly simple batteries of tests and measurements have been devised to classify twins as monozygotic or dizygotic with a high degree of reliability.

In a sense the determination of the degree of similarity for any trait in monozygotic twins provides a basis for differentiating between environmental and hereditary influences in the acquisition of the trait. The analysis could best be made by comparing the trait similarity of twins reared together and twins reared apart, but the number of monozygotic twins reared apart are so few as to make a significant amount of data quite unavailable.

In the absence of such comparative data the genetic analysis becomes essentially a qualitative one. In such an instance the demonstration of hereditary influence is at best only that of showing the degree of similarity for a given trait in monozygotic twins to be higher than could be expected, or hoped for, on the basis of existing knowledge concerning the influence of environment on the trait in question.

The quantitative specification of a given trait may be obtained in one of several ways, such as by a simple measurement of magnitude, by a determination of orientation or vector characteristics, by count, by classification, by a complex set of measurements expressed as a ratio, a product, a difference, etc. In this sense it becomes possible to manu-

---

*Read before the annual meeting of the American Academy of Optometry, Chicago, Ill., December 16, 1947. For publication in the October, 1948, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Optometrist. Fellow, American Academy of Optometry. Member of faculty.

facture mathematically a virtually infinite number of "traits."

The values obtained by the quantitative specification of such traits often appear to distribute themselves at random among individuals, that is, apparently without regard to their genetic interconnections or the specified environmental conditions. Insofar as all traits must have either a genetic or an environmental etiology, the failure to detect a statistical relationship between a given trait and the specified genetic or environmental conditions simply means that the appropriate genetic or environmental conditions have not been identified for the trait. Conversely, if a significant statistical correlation for a trait is found between pairs of individuals selected on a genetic basis, as in the case of monozygotic twins, it must be inferred either that the trait has a genetic etiology or that the criterion employed in selecting the pairs of individuals acts simultaneously as a criterion for selecting pairs according to the environmental conditions responsible for the trait. If, in spite of a statistically significant correlation, the possibility of a genetic influence must for any reason be regarded as untenable, then at least a certain degree of definition or isolation of the environmental conditions producing the correlation has been accomplished. Hence, if a statistically significant correlation for a given trait is found in monozygotic twins, it must be assumed that the trait is genetic in origin or that the typical manner in which the twins are reared provides the necessary control of the environmental condition acting as the etiological agent.

Incidental to these considerations is the fact that, if the average value and the distribution of values for a given trait in a group of individual monozygotic twins is not different from those for a random population, then the suspected etiology of the trait, whether genetic or environmental, cannot be assumed to be peculiar to monozygotic twins.

Accommodative convergence is expressed as a ratio. It is defined[2,3,4,5] as the change in convergence of the lines of sight of the two eyes associated with a change in accommodation. Inasmuch as the total or resultant convergence of the two eyes in ordinary binocular fixation may be considered to be the sum of several types or components of convergence it is necessary to isolate experimentally the accommodative convergence from the other convergence components in order to demonstrate or measure the degree of relationship between accommodation and accommodative convergence.

This investigation was designed to determine whether or not the ratio of accommodative convergence to accommodation, called the ACA ratio[3,4,5], shows an intra-pair similarity in monozygotic twins.

The investigation was made possible by an appropriation of funds from the Graduate School of the Ohio State University and by arrange-

ment with David C. Rife of the Department of Zoology. The subjects were volunteer identical twins attending a convention of twins in Grand Rapids, Michigan, on August 31, 1946. The ACA measurements were made as a part of a battery of tests and measurements conducted by a staff of students and investigators working in cooperation with Professor Rife.

EQUIPMENT AND PROCEDURE

The convergence measuring instrument consisted of a model 45B Troposcope[6] mounted on a standard ophthalmic instrument table adjustable for height so that the subject could be seated comfortably during the test. The optical system of the troposcope is illustrated in

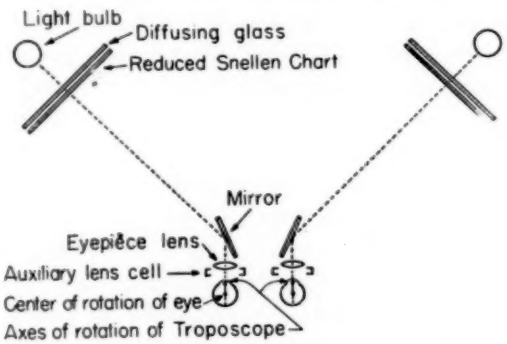


Fig. 1. Optical system of the instrument used to measure the accommodative convergence.

Figure 1. The fixation targets consisted of a pair of identical lantern-slide reproductions of a standard Snellen test chart reduced in size to provide an assortment of lines of letters representing various degrees of visual acuity corresponding to 20/15, 20/20, 20/25, etc. The stimulus to accommodation was controlled by means of a pair of —0.50 and a pair of —4.50 diopter spherical lenses which could be alternately inserted in the auxiliary lens cells of the troposcope.

The twins who volunteered for the tests were examined in the order in which they appeared at the convention registration desk. The observations and questions preliminary to measuring the ACA ratio were designed to disqualify the following:

1. Fraternal twins. The classification of twins was made by Rife, who supervised the other tests. All doubtful cases were also excluded. The three pairs of fraternal twins represented in Figures 2 and 3 were included in error.

2. Twins over 35 and under 10 years of age.

3. Uncooperative twins or twins unable to follow instructions.

4. Twins showing ocular paralysis upon inspection of the ocular rotations and versions.

5. Twins with glasses indicating more than 3.00 diopters of ametropia in any meridian.

6. Twins unable to read the 20/20 letters with each eye during any part of the test.

None of the twins showed, upon general external inspection, any inflammatory ocular condition, ptosis of the lids, corneal scars, corneal, lenticular, or anterior chamber opacities, or abnormally large, small, unequal, or immobile pupils.

The glasses worn by the subjects were classified as *plus* (+) if the inspection of image movement in the lenses showed *against* motion in all meridians; as *minus* (—) if all meridians showed *with* motion; *mixed*, when both *with* and *against* motion could be observed; and *none* (0) if the subject had no glasses with him, or used his glasses for reading only, or reported that he saw distant objects clearer without glasses. Those classified as *none* (0) wore no glasses during the test. The classifications are indicated in Table I.

Both a corneal reflex test and an alternate occlusion test for squint were made on each subject. In addition the name, age, and sex of each were recorded.

The subsequent procedure for the first member of each pair of twins was as follows:

1. The table, chair, and instrument were adjusted for comfort and proper alignment of the two eyes in front of the lens apertures.

2. The —0.50 D. spheres were inserted in the auxiliary lens cells, the right eye chart was illuminated, and the subject was asked to read aloud the row of smallest letters that he could read, starting with the larger letters near the top of the chart if necessary. If the subject read the 20/20 letters or better, the test was repeated with only the left eye chart illuminated. If the subject again read the same row of letters he was instructed to continue to read these letters alternately forward and backward, slowly, and aloud. During this performance the operator alternately illuminated the right and left eye charts and gradually changed the relative convergence positions of the troposcope arms until the eyes were observed to cease to "move" or "jump" with the alternate exposure of the right and left eye charts. The operator used a bracketing technique to determine the point at which the fixational movements ceased. The angle of convergence of the eyes at this point, as indicated by the scale on the instrument, was recorded to the nearest centrad, with convergence from parallelism being recorded as plus (+) values and divergence as minus (—) values.

TABLE I

Complete Record of All Data Obtained on 30 Pairs of Identical Twins

Twin No.	Sex	Age	Type of Rx.	Convergence in Centrads Through —0.50 No. 1	Through —0.50 No. 2	Through —4.50 No. 1	Through —4.50 No. 2	ACA Ratio
1a	F	22	0	2	2	16	17	3.6
b	F	22	0	—2	0	8	11	2.6
2a	F	19	0	1	1	25	26	6.1
b	F	19	0	5	5	26	26	5.2
3a	M	20	0	0	0	7	7	1.8
b	M	20	0	1	2	13	13	2.9
4a	M	14	0	—2	0	22	26	6.2
b	M	14	0	3	0	22	20	4.9
5a	F	19	0	7	6	27	28	5.2
b	F	19	0	5	4	18	18	3.4
6a	F	18	0	4	3	28	25	5.8
b	F	18	0	1	2	25	24	5.8
*7a	M	23	0	—14	—14	—7	—6	1.9
b	M	23	0	—10	—8	—4	—6	1.0
8a	M	23	—	2	2	16	15	3.4
b	M	23	—	1	1	13	12	2.9
9a	M	16	0	0	—2	16	14	4.0
b	M	16	0	0	1	12	13	3.0
10a	F	19	+	8	9	18	19	2.5
b	F	19	+	12	10	22	24	3.0
11a	M	28	—	0	2	10	13	2.6
b	M	28	—	1	0	19	18	4.5
12a	M	32	0	—2	—3	12	10	3.4
b	M	32	0	2	2	25	20	5.1
13a	F	17	0	0	—2	12	17	3.9
b	F	17	0	0	0	14	17	3.9
14a	F	23	—	4	2	12	19	3.1
b	F	23	—	2	—1	12	13	3.0
15a	F	20	0	—1	—2	4	10	2.1
b	F	20	0	5	—1	17	17	3.8
16a	F	16	0	—1	—3	9	13	3.2
b	F	16	0	1	0	13	16	3.5
17a	M	21	0	—2	—4	9	8	2.9
b	M	21	0	2	1	12	12	2.6
18a	F	25	+	—4	—3	11	11	3.6
b	F	25	+	—2	—4	11	10	3.4
19a	F	12	0	6	3	22	18	3.9
b	F	12	0	0	0	15	16	3.9
20a	F	16	0	0	2	12	9	2.4
b	F	16	0	0	—1	7	8	2.0
21a	F	35	—	1	0	10	14	2.9
b	F	35	—	—2	—1	9	8	2.5
22a	M	17	0	—2	0	10	10	2.8
b	M	17	0	1	0	10	10	2.4
23a	F	11	0	5	4	26	30	5.9
b	F	11	0	3	6	22	24	4.6
24a	F	18	0	1	2	20	21	4.8
b	F	18	0	2	2	16	19	3.9
25a	F	21	0	—2	—2	14	14	4.0
b	F	21	0	0	—1	17	17	4.4

*Twins No. 7 both showed exotropia by the alternate occlusion test and upon inspection of the corneal reflexes.

Table I continued on page 485.

Table I continued from page 484.

Twin No.	Sex	Age	Type of Rx.	Convergence in Centrads Through —0.50 No. 1	Through —0.50 No. 2	Through —4.50 No. 1	Through —4.50 No. 2	ACA Ratio
26a	F	25	0	0	—1	10	8	2.4
b	F	25	0	—3	—4	7	9	2.9
27a	F	16	0	2	3	15	17	3.4
b	F	16	0	0	2	18	20	4.5
28a	F	20	—	2	0	7	11	2.0
b	F	20	—	2	0	9	10	2.1
29a	M	25	—	4	4	14	15	2.6
b	M	25	—	—2	—2	7	9	2.5
30a	M	14	0	—1	—3	10	10	3.0
b	M	14	0	0	—2	11	10	2.9
Mean		20.2						3.48
Standard Deviation		5.2						1.08

3. The —4.50 D. spheres were inserted in place of the —0.50 D. spheres and the above procedure was repeated.

4. The test was repeated with the —0.50 D. spheres.

5. The test was repeated with the —4.50 D. spheres.

The ACA measuring procedure for the second member of each pair of twins was the same as for the first except that the —0.50 D. and —4.50 D. spheres were inserted in the opposite sequence.

RESULTS

All of the original data are included in Table I.

The difference between the two convergence findings through a given lens power gives a limited indication of the accuracy attained in the convergence measurements. The average of these differences for the 60 subjects (30 sets of identical twins) when the —0.50 D. spheres were used was 1.3 centrads. When the —4.50 D. spheres were used the average difference was 1.8 centrads.

The accuracy of the accommodation measurements is limited by the assumption that the stimulus to accommodation is a measure of the actual accommodation when the 20/20 test letters are readable. The basic error involved is the lag of actual accommodation behind the stimulus to accommodation as permitted by the depth of focus for 20/20 letters. Since both the —0.50 D. and the —4.50 D. spheres provide positive amounts of stimulus to accommodation for emmetropes and hyperopes, and for myopes of less than 0.50 diopters, the error may be assumed to be minimized by the fact that the lag would operate in the same direction at both levels of accommodation and so would tend to be eliminated in the computation of the difference in accommodation at the two levels. The extent to which the error is likely to affect the ACA ratio finding has been described previously by both Morgan[7] and Hofstetter[3]. The manner in which it would affect the

results of this investigation would be to reduce the apparent average value of the ACA ratio for the group and to reduce the apparent degree of intra-pair correlation of the ACA ratios.

The ACA ratio for each twin is computed in accordance with the analysis diagrammatically represented in Figure 2 for a representative pair of twins, Numbers 23a and b of Table I. The ratio value expresses the number of centrads of accommodative convergence asso-

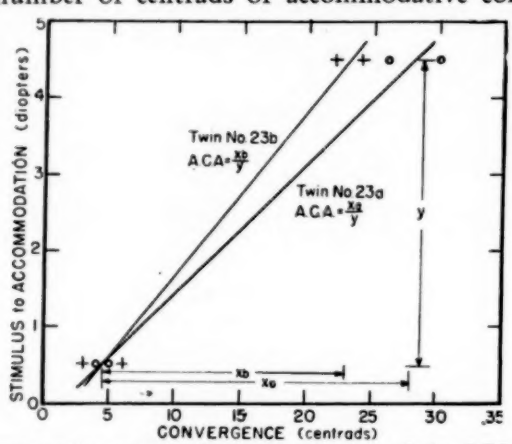


Fig. 2. Diagrammatic analysis of the computation of the ACA ratio in a sample pair of twins.

ciated with one diopter of accommodation. This value is obtained from the data for a given twin by subtracting the mean of the convergence findings through the —0.50 D. spheres from the mean of the con-

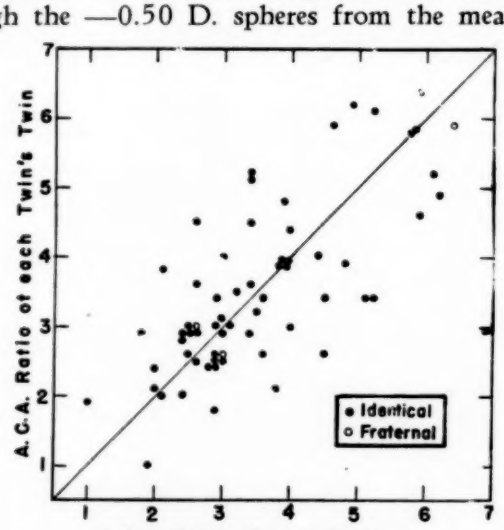


Fig. 3. ACA ratio double-entry scatterplot.

vergence findings through the —4.50 D. spheres and dividing by 4. The ACA ratio values so obtained are included in Table I.

The interpretation of twin data has represented a relatively unique and infrequently dealt with problem in statistics. One approach is that of Holzinger[8] who treats twin data as a problem in "intraclass correlation."

Intraclass correlations are obtained by forming a symmetrical or double-entry table or scatter diagram. Instead of entering each pair of observations once in such a table or diagram, it is entered twice, the coordinates of the entries being the same numbers, their order being reversed. Thus, if measurements of the ACA ratios of a pair of twins are found to be 4.2 and 5.0, these two values are entered in the XY scatter diagram as $X = 4.2$, and $Y = 5.0$ and also as $X = 5.0$ and $Y = 4.2$. Such a diagram is Figure 3. If N is the number of pairs of twins, there will thus be 2N entries in the correlation table or scatter diagram.

Because of the double entries in this arrangement,

$$\Sigma X = \Sigma Y \tag{1}$$

and

$$\Sigma X^2 = \Sigma Y^2 \tag{2}$$

If M denotes the mean for all of the twins, and N denotes the number of pairs of twins, then

$$M = \frac{\Sigma X}{2N} = \frac{\Sigma Y}{2N} \tag{3}$$

Using the ungrouped product moment method [9] of analysis for the standard deviation (σ) from the mean,

$$\sigma_x = \sigma_y = \sqrt{\frac{\Sigma X^2}{2N} - \left(\frac{\Sigma X}{2N}\right)^2} \tag{4}$$

and the coefficient of correlation r is represented by,

$$r_{xy} = \frac{2N \Sigma (XY) - (\Sigma X)^2}{2N \Sigma X^2 - (\Sigma X)^2} \tag{5}$$

The standard deviation of the coefficient of correlation due to the sampling error is denoted by the usual formula,

$$\sigma_r = \frac{1 - r^2}{\sqrt{N}} \tag{6}$$

In the above formulas no corrections are made for the smallness of the sample or for possible skew distribution.

The above formulas give a mean ACA ratio of 3.48 for the 30 sets of identical twins, a standard deviation of 1.08, and a coefficient of raw intraclass correlation of the ACA ratios of 0.67 with a standard deviation of 0.10. This coefficient is not corrected for attenuation due to experimental error. The adjusted coefficient would be slightly higher.

Another approach to the statistical analysis of twin data is illustrated by the following analysis of the data in Table I as made at the Ohio State University Statistics Laboratory.[12]

"We seek an answer to the question: Does the ACA ratio vary more between families than it does between the twins?

"Let x_{ij} be the ACA ratio of the jth twin in the ith family. $x_{i.}$ denotes the mean of x_{ia} and x_{ib} and x denotes the grand mean.

"We make the following assumptions:

1. The variation between x_{ia} and x_{ib} is random variation.
2. The value of x_{ij} can be expressed as the sum of a family effect m_i ($\Sigma m_i = 0$), a general mean m, and a random variable E_{ij}.
3. The E_{ij} are independently and normally distributed with common mean O and common variance σ^2

"These assumptions can be expressed by

$$(A) \qquad x_{ij} = m_i + m + E_{ij}$$

"The hypothesis we set up to test is as follows: The family effects are all zero, i.e.

$$(H) \qquad m_i = 0 \qquad \text{for all } i$$

"This assumption and hypothesis lead to the customary decomposition of sums of squares as exhibited in this table:

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Square
Among families	$2\sum_i (x_{i.} - x)^2 = 69.4575$	29	2.395
Error	$\sum_{ij} (x_{ij} - x_{i.})^2 = 13.2550$	30	.442
Total	$\sum_{ij} (x_{ij} - x)^2 = 82.7125$	59	

"In order to test the hypothesis H we use the F test where F is the quotient of two variances. Here

$$F = \frac{2.395}{.442} = 5.42$$

If the value of F is large enough we reject the hypothesis H. This means, essentially, that the variation among families is significantly greater than what has been termed random variation or variation between the individuals in a pair of twins. If F is small, the hypothesis H cannot be rejected. In this case no statement can be made about the relative variation in twins and among families.

"In our case 5.42 is significantly large. If the hypothesis is true, the probability of obtaining $F \geq 2.38$ is only .01.

"Conclusion: The variation in ACA ratio between families of twins is greater than the variation between the members of ' families."

According to the report from the Statistics Laboratory the double-entry method for finding a correlation coefficient does not readily permit an evaluation of the degree of significance of the correlation. It was for this reason that the latter analysis was carried through. The double-entry analysis was carried through for purposes of comparison of results to twin data on other traits tabulated by Newman, Freeman, and Holzinger.[8]

The age range for the group was from 10 to 35 years with a mean of 20.2 and a standard deviation of 5.2 years. As a check against the possibility that age was a factor in determining the ACA ratio, the average ACA ratio for each pair of twins was plotted against the age in Figure 4. The resultant scatter diagram suggests no significant cor-

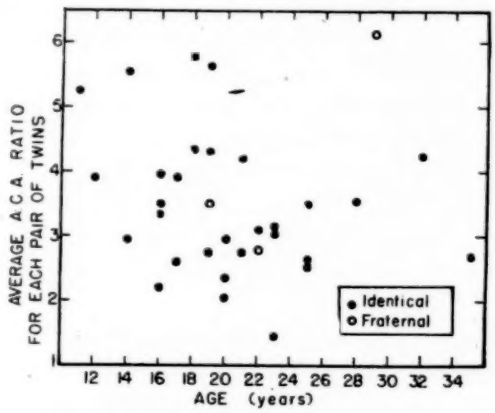


Fig. 4. Scatterplot of ACA ratio and age.

relation. The product-moment technique gives a coefficient of correlation of —0.23 between ACA ratio and age, with a standard deviation of 0.17.

A general inspection of the distribution of the ACA ratios and the distribution of ages shows them to be reasonably normal.

DISCUSSION AND CONCLUSION

The mean ACA ratio of 3.48 for the 30 sets of identical twins, with a standard deviation of 1.08, compares favorably with the mean and standard deviation values obtained by Morgan[7] and Hofstetter[10] on groups of individuals with normal binocular vision, and with the values obtained by Hofstetter[3] on a group of concomitant squinters. Although

the above mean value of 3.48 is slightly less than the means obtained by either Morgan or Hofstetter the difference is not to be treated as statistically significant, because of the smallness of the sample. If the difference were assumed to be real it might be accounted for in the experimental error allowed by using the stimulus to accommodation as a measure of the actual accommodation as discussed above. If it is concluded that the difference is not real, or that it is attributable to experimental deficiencies, then it may also be concluded that twinship in itself bears no relationship to the development of the ACA ratio. That is to say that, so far as the ACA ratio is concerned, twins on the average are not different from other individuals.

The coefficient of correlation of —0.23 between age and ACA ratio, with a standard deviation of 0.17, is not significantly different from a zero correlation. This observation compares favorably with the writer's[11] previous observation of the absence of a relationship between ACA ratio and age. That the —0.23 coefficient is not significant is very practically illustrated by the fact that the inclusion of the ACA ratio and age data for the three sets of fraternal twins otherwise excluded from this study would have reduced the coefficient for the total of 33 sets of twins to —0.05 with the same standard deviation of 0.17. Finally, it should be pointed out that the minus correlation is opposite to the correlation that would be expected on the basis of the occasionally proposed theory that the ACA ratio should increase with the reduction in the amplitude of accommodation occurring with age. To the writer's knowledge there are no theories that would call for a reduction of ACA ratio with age.

The coefficient of intraclass correlation of 0.67 for the ACA ratios in identical twins may be considered relatively high, in view of the many sources of measurement error permitted in this experimental procedure. This coefficient is slightly lower than most of the published coefficients obtained in other physical and biological data on identical twins[8] which by their anatomical or physiological nature are conceded to be dependent mainly on heredity. To the writer's knowledge none of the identical twin correlations for traits believed to be influenced mainly by environment have approached this degree of correlation. The standard deviation of 0.10 of the coefficient of correlation obtained in this investigation does not preclude these comparisons.

In conclusion it may be restated that the variation in ACA ratios between the identical twins herein studied is significantly less than the variations between pairs or families. The high similarity points either to the inference that there is a genetic basis for accommodative convergence or that the environmental factors influencing the development

of accommodative convergence are remarkably and selectively similar for the two members of each pair.

REFERENCES

1. Rife, David C., Heredity and Twins, Scientific Monthly, Vol. 53, August, 1941, pp. 148-154.
2. Maddox, E. E., The Clinical Use of Prisms, Fifth Edition, London, 1907, pp. 158-177.
3. Hofstetter, H. W., Accommodative Convergence in Squint, American Journal of Optometry and Archives of American Academy of Optometry, Vol. 23, No. 10, October, 1946, pp. 417-441.
4. Fry, Glenn A., Fundamental Variables in the Relationship between Accommodation and Convergence, Optometric Weekly, Vol. 34, Nos. 6 and 7, March 18 and 25, 1943, pp. 153-155 and 183-185.
5. Hofstetter, H. W., Certain Variations in the Angle of Deviation in Concomitant Squint, American Journal of Optometry and Archives of American Academy of Optometry, Vol. 24, No. 10, October, 1947, pp. 463-471.
6. Orthoptic Procedure with the Troposcope, The Wottring Instrument Company, Columbus, Ohio, 1944.
7. Morgan, M. W., Jr., Accommodation and Its Relation to Convergence, American Journal of Optometry and Archives of American Academy of Optometry, Vol. 21, No. 5, May, 1944, pp. 183-195.
8. Newman, H. H., Freeman, F. N., and Holzinger, K. J., Twins: A Study of Heredity and Environment, University of Chicago Press, Chicago, Illinois, 1937.
9. Arkin, H., and Colton, R. R., An Outline of Statistical Methods, College Outline Series, Barnes & Noble, New York, 1938.
10. Hofstetter, H. W., The Proximal Factor in Convergence and Accommodation, American Journal of Optometry and Archives of American Academy of Optometry, Vol. 19, No. 2, February, 1942, pp. 67-76.
11. Hofstetter, H. W., The Zone of Clear Single Binocular Vision, Part II, American Journal of Optometry and Archives of American Academy of Optometry, Vol. 22, No. 8, August, 1945, pp. 361-384.
12. Whitney, D. Ransom, The ACA Ratio in Twins, Special report from the Ohio State University Statistics Laboratory, January 29, 1948.

ABSTRACTS

A SUBJECTIVE TEST FOR ASTIGMATISM, A. Otten, The Optician, (London), Vol. 113, No. 2936, July 11, 504-506, 1947.

This test is a combination of the rotating astigmatic dial and the Scheiner-Rohr principle[1] as used on the continent. The rotating astigmatic dial is comprised of a broken double cross on a white background with the usual axis-meridian figures on the chart supporting the dial. The occluder is an opaque disc which has two holes, each 1 mm. in diameter and 3 mm. apart in the center of the disc. The suggested technique follows: To determine the principal axes, the dial is rotated until, in one meridian, the rectangle on the outside and the squares in the center (from the broken double cross on the dial) form one continuous line and do not appear to be laterally displaced in respect to each other. The dial is now set in this direction and the occluding disc with its two holes is put in front of the eye under examination with the position of the two holes corresponding with that of the axis of the dial. Spherical lenses are then placed before the eye until the lines in this direction are black and well defined. This procedure is repeated in the other meridian by turning the occluding disc 90 degrees. C. C. K.

1. An occluder disc with four very small holes in the center. When the ametropic patient observes an object through these four holes he will project all four circles simultaneously. The emmetropic patient will project but one circle. Obviously, very accurate fixation and placement of the occluding disc is required in using this technique.

CLINICAL INVESTIGATION OF A METHOD OF TESTING PHORIA AT FORTY CENTIMETERS*

Monroe J. Hirsch†
School of Optometry, The Ohio State University
Columbus, Ohio

It has been shown in a previous exploratory paper[1] that some revision of the Thorington test for phoria at 40 cm. might better satisfy the criteria of (a) repeatability, (b) simplicity of operation, and (c) more nearly full accommodation for the stimulus in play than does the more customary diplopia or prism dissociation test of von Graefe. The present study was designed to investigate clinically the modification of the Thorington test previously described.

Methods: The modified Thorington test and the prism diplopia test were administered to 200 patients at the Ohio State University Optometry Clinic by one of the senior students as part of the regular clinic examination and again by one of the instructors within one hour.[a] There were then four tests; Thorington test administered by a student (Ts), Thorington by an instructor (Ti), and the diplopia test administered by both student and instructor (Ds and Di). The instructor usually was not aware of the student's findings and his measurements were made independently. Neither the student examiner nor the instructor knew the numerical values assigned to the various letters of the Thorington target, to be described. Both students and instructors followed the outline presented below as closely as possible.

Diplopia or dissociated prism test: The patient was seated behind a phoropter containing the subjective correction, and an 8△ prism base-down was placed before the left eye. Before the right eye a Risly prism, set at 15△ base-in was placed. The reading card, a reduced Snellen chart, was placed at 40 cm. The patient was instructed to find the lowest line that he could read in the upper (stationary) image. While the patient slowly read this line forward and backward, naming each letter aloud, the lateral prism was reduced. The patient was instructed to report vertical alignment. The student examiner and the instructor took a single reading only.

---

*Submitted on May 28, 1948 for publication in the October, 1948, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Optometrist. Member of faculty. Fellow, American Academy of Optometry. Now member of faculty, Vision Laboratory, Department of Physiology, Medical School, Stanford University, California.

a. In all, 54 senior students and 12 clinic instructors participated. The author expresses gratitude to all for excellent cooperation.

Thorington Test (Ohio State Modification): The patient was placed behind the phoropter as in the above-described test. A multiple Maddox rod was placed before the right eye with the cylinder axis horizontal so that a vertical streak was seen. Illumination on the card, placed at 40 cm., was the same as for the other clinical near point tests. The card contained four horizontal lines, each consisting of 34 characters (26 letters and the numbers from 2 to 9). The placement of the characters was made in a random fashion when the card was designed and the order for each of the lines was different. The first line, reading from left to right, was 8, X, W, I, Y, 5, etc., while the second line was 5, R, 8, V, X, 6, Q, etc. The lines were separated vertically by 9 mm. and the letters in each line were exactly 4 mm. apart. The type was approximately 0.92 mm. in height for the upper line, the letters being roughly 3/5 as wide as they were high. It may be mentioned here that were a new card for general use being designed, a larger size for the upper line, and omission of the smallest line would be desirable. The patient was instructed to read the lowest line that he could; most patients read the first or second lines, a very few the third, and none the fourth.

The examiner placed an exposed ophthalmoscope bulb directly behind a hole, 1 mm. in diameter, which had been drilled beneath the 19th letter from the left and halfway between the second and third lines. The vertical streak seen by the eye with the Maddox rod before it was sufficiently large to cross all four lines. The range of the card was from 18△ exophoria to 15△ esophoria. The patient having selected the smallest type which he could read, read aloud the letters from left to right, continuing until he reached the letter closest to the streak. Only a single trial was made, the letter and line being reported. At a later time, the scores were converted into prism diopters of esophoria or exophoria.

Results: The means and standard deviations for the 200 patients for each test are presented in Table 1.

TABLE 1

Test	*Mean*	*Standard Deviation*
D_s	—4.03[b]	6.42
D_i	—4.32	6.10
T_s	—3.15	6.24
T_i	—3.12	5.92

b. A minus sign (—) indicates exophoria, while absence of sign indicates esophoria.

The mean for Ds differed significantly from that for Ts to the one in 7,000 level, while the probability that a difference as large as that between Di and Ti could have occurred by chance was less than one in 10,000. The differences between means as determined by students and as determined by instructors did not differ significantly, for either test T or test D.

Four correlation coefficients were obtained and are presented in Table 2.

TABLE 2

Variable 1	*Variable 2*	*Correlation Coefficient (r)*	r^2
D_s	D_i	0.86	0.74
T_s	T_i	0.94	0.88
D_s	T_s	0.74	0.55
D_i	T_i	0.84	0.71

As in the preceding preliminary report[1], the striking feature of the data is the magnitude of all coefficients, especially high for an experiment involving thresholds based upon a single observation and numerous student and instructor experimenters. The difference between the reliability coefficient for the prism diplopia test (0.86) and for the Thorington test (0.94) could have occurred by chance less than one in ten thousand times. The difference between the correlation coefficient between tests for student examiners (0.74) and instructors (0.84) was significant to the seven in 1,000 level.[c]

On the basis of the above findings, the following conclusions seem justified:

A. The Thorington test with the modifications described above results on the average in findings one prism diopter less exophoric at 40 cm. than does the diplopia test. This is in part at least, due to the better control of accommodation in play. This result, similar to that found in the exploratory study, was discussed in that paper.

B. An average value for phoria at 40 cm. seems to be 3△ of exophoria if the Thorington test is used, and 4△ of exophoria for the prism diplopia test. The value of 6△ sometimes used seems to be unduly high as numerous authors cited in the exploratory paper have found.

C. The reliability coefficients of 0.86 for the diplopia test and 0.94 for the modified Thorington test are high for this type of measurement; the difference between the two reaches a significance level of less than one in 10,000. Thus, for the diplopia test 74 per cent of the variance

c. Significances determined by Fisher's Z_R method. See R. A. Fisher, Statistical Methods for Research Workers, 1936, Section 35.

in students' findings was associated with variance in instructors' findings, while for the Thorington test 88 per cent of the variance in one was associated with variance in the other.[d]

D. The correlation coefficients between the two different tests of 0.74 for students and 0.84 for instructors are only slightly lower than the reliability coefficients and indicate that for the most part both tests are measuring the same thing. The correction for attenuation has not been made since the similarity of tests is clearly demonstrated by the similarity of correlation coefficients between tests and the reliability coefficients.

E. The correlation between tests was higher for instructors than for students, the difference being significant to the seven in 1,000 level. Since the Thorington test had not been formerly employed by either group, this difference is possibly due to difference in ability to administer the diplopia test or else due to practice effect since the instructor's test always followed that of the student examiner.

General Conclusions: The Ohio State modification of the Thorington test seems to possess the following advantages over the more customarily employed dissociated prism test:

(a) Greater repeatability
(b) Better control of accommodation
(c) Simpler to explain to patient and hence slightly less time consuming.

All three of the above effects are, however, slight and perhaps an equally important conclusion is that either test, if carefully administered, is a highly reliable test.

The average values suggested by this study are 3△ of exophoria for the Thorington test and 4△ for the diplopia test instead of the more customary 6△ of exophoria. It is of course necessary to consider the magnitude of the standard deviation, approximately 6△ for all tests in the interpretation of any individual measurement.

---

d. The interpretation of the square of the correlation coefficient as per cent of associated variance is a useful one frequently employed.

REFERENCES

1. Hirsch, Monroe J. and Bing, Lois B., The Effect of Testing Method on Values Obtained for Phoria at Forty Centimeters. Am. J. Optom. & Arch. Amer. Acad. Optom. 25. 9. 407-416. 1948.

INVESTIGATION OF THE VARIATION AND THE CORRELATION OF THE OPTICAL ELEMENTS OF HUMAN EYES*§

Solve Stenstrom†
Med. lic., Gbg.
Translated by Daniel Woolf‡
Columbia University Optometry Laboratory
New York, New York

PART VI—CHAPTER III—SUMMARY

C. THE JOINT INFLUENCE OF THE OPTICAL ELEMENTS IN THE FORMATION OF THE TOTAL REFRACTING POWER.

In the foregoing discussion we have found that the dioptric elements of the eye (corneal refracting power, depth of the anterior chamber, and the refracting power of the lens) individually show normal distribution; and that they do not vary independently but are more or less correlated. As a consequence of this association, the total refracting power has a lower standard deviation than that which would be expected on the basis of a random combination of the individual elements. But since the correlation is not high, the total refracting power still exhibits a large standard deviation.

The length of the axis of the eye, which is a measure of the position of the receiving surface with respect to the optical system, shows a totally different picture in its variation. Here, as we have found, the departure from a normal distribution curve is considerable, and shows itself in two directions; on one hand as an obvious skewness with a long extension in the direction of increased length, and on the other hand as a marked leptokurtosis, namely as an exaggerated number of median cases as compared with the extremes. As was pointed out, the abnormal distribution of the axial length is very likely due to the lack of homogeneity of material. By exclusion of the well-defined group of eyes which display fundus changes of a myopic character, a distribution is obtained which, while it is not normal, is drawn considerably nearer to the normal, and which to all appearances shows no skewness.

Since for all purposes the refractive error is a linear function of the axial length vergence and the total refracting power, and since the latter

†From the Ophthalmological Clinic of the University of Upsala. Professor Frederick Berg, Chief
‡Optometrist. Fellow, American Academy of Optometry.
*UPSALA 1946. Appelbergs Boktryckeri. A.-B.
§The last of six chapters.

is normally distributed, it follows that a *skewness in the refractive error distribution can have its basis only in the skewed distribution of the axial length.* Yet one must note that the smaller skewness in the axial length cannot cause the very significant skewness in the refractive error distribution. It can be remarked here that the skewness found in published curves of refractive error distributions is in part based on the use of the correction lens values. It should be evident that this introduces an artificial skewness which becomes larger when the lens is placed further away from the eye. Since the conventional vertex distance (12 mm.) is completely arbitrary, it cannot be employed in a statistical analysis. *In order to obtain the true refractive error, it is self evident that the principal point refraction (axial refraction) must be known.* When the distribution curve for the correction lens refraction is transformed to principal point refraction,[39] we obtain a curve whose limits are approximately symmetrical. The extreme values for correction lens refractive error are taken to be approximately —40 D., (Ergglet: that of Oliver, as cited by Ergglet, who mentions a case of —60 D. is uncertain because the vertex distance is not given) and +20 D. (Leber +16, Osterroth, Schon + 20 D., Borman, Donders +24 D.; all cited by Ergglet). Thus the corresponding values for the principal point refraction are —25 D. to +28.5 D. By this transformation, the refractive error curve takes on nearly symmetrical limits, but the distribution remains skewed—the frequency of higher myopia is considerably larger than the frequency of higher hyperopia. Wibaut (a) has worked on this question but has established only that by taking the transformation into consideration the refractive error changes by not more than 1 D.

The skewness of the distribution curve for the principal point refraction is not larger than that which the skewness of the axial length distribution can explain. In general, the same can be said of the relatively overweighted extremes present in the refractive error distribution.

The refractive error can be considered as a linear function of the total refracting power and of the reduced vergence of the axial length (B_1). The error introduced by the following computation of the standard deviation of the refractive error, where the vergence of the axial length is used instead of the vergence from the principal point to the fovea (B), is insignificant. We obtain the following formula:

$$\sigma A \approx \sigma (B_1 - D) \qquad \ldots\ldots\ldots\ldots (14)$$

By this formula we can compute the σ of the refractive error from the known σ of the vergence of the axial length and that of the total refracting power together with their coefficient of correlation provided

[39] By equation (2) on page 292.

both variables are normally distributed. Since this is not the case, we cannot expect particularly good agreement between the computed and the true value. We found a value of $\sigma A = \pm 1.87$ D., while for our material the value is probably ± 2.20 D. Thus the agreement is poor even when we consider that B_1 must have a somewhat smaller σ than B. The computed σ is somewhat too small for this reason. We do not know what factors lie behind the heterogeneity of the axial length distribution, but we will postulate temporarily that conus eyes form a distinct group, according to the theory of Scheerer and Betsch, and will divide the material accordingly.

The axial length of conus-free eyes shows a variation which approaches a normal distribution curve; the mean is 23.83 ± 0.031 mm. and $\sigma = \pm 0.901 \pm 0.022$ mm. The total refracting power shows a normal variation with $\sigma = \pm 1.777 \pm 0.043$ D. The coefficient of correlation between total refracting power and the vergence of the axial length is $+0.645 \pm 0.20$ for this group. Based on this we obtained the value ± 1.703 D. for σA by computation. Since σ of the refractive error for this group is $\pm 1.705 \pm 0.041$ D. the agreement is very good. Yet this does not show that conus-free eyes form a homogeneous or uniform

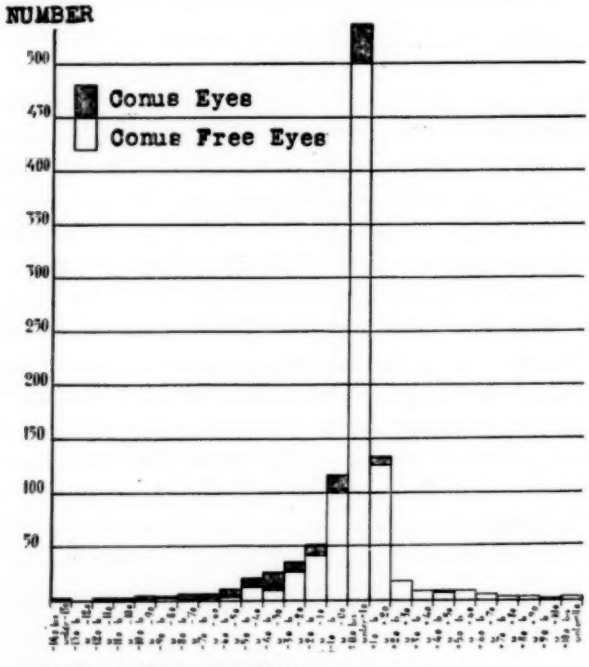


Fig. 16. Distribution of Refractive Error of all Cases with Conus eyes Indicated in Gray.

group. The distinct leptokurtosis (compare with Figure 16) demonstrates that this portion contains several sub-groups with differing distribution curves. As Berg has shown, the stronger hyperopes probably are a group which, with others, help to form the peculiar distribution of the axial length.

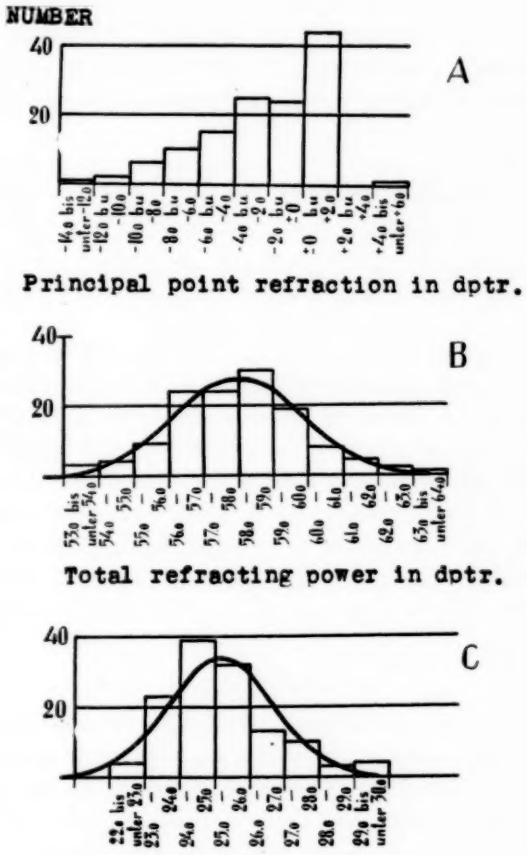


Fig. 17. Distribution Curves of Principal Point Refraction, Total Refracting Power and Axial Length in Conus Eyes.

The distribution of conus-eyes with regard to refractive error, total refracting power and axial length is shown in Figure 17. As can be seen, the refractive error distribution is extremely asymmetrical, while the distribution of the total refracting power can be proven normal for this conus group ($\frac{\chi^2}{m} = 0.60$ for $m = 5$ against an allowed value of 3.641). The distribution of the axial length appears to show a skew-

ness and a kurtosis, but the material is not sufficiently extensive to prove that a reliable departure from normal distribution exists. ($\frac{\chi^2}{m} = 3.873$ for $m = 3$ as against a maximum allowed value of 4.719). The large degree of skewness in the refractive error distribution can be explained only by skewness in the distribution of the axial length. Indeed, it is improbable that the conus eyes are actually an individual group as accepted by Scheerer and Betsch. The correlation between axial length vergence and total refracting power is significantly weaker for these eyes than for the others, $r = +0.28 \pm 0.081$.

The investigation has shown with great probability that the refractive error distribution arises by the addition of several biologically different groups with differing characteristics, the latter being principally the variation of the axial length and the covariation of the axial length with the other elements. This does not give an answer to the question concerning the nature of the different groups.

For the solution of this question, studies of heredity are essential first of all. The total refracting power is such a complex thing that its behavior in heredity becomes complicated and difficult to estimate. Therefore, first studies on the inheritability of the separate optical elements should be started as has been done in the case of the corneal refracting power. By the method of Rushton we now have a means of determining the axial length in a manner which permits studies of the correlation of axial lengths with the other optical elements. It can give us a significantly clearer concept of the elements which determine the refractive error.

SUMMARY

Earlier statistical investigations of the optical elements of the human eye and their connection with each other and with the refractive error have made it clear that the refracting power of the cornea and the depth of the anterior chamber show a normal variation and that the first named quantity reveals a slight negative correlation to the refractive error, while there is a more pronounced negative correlation between the depth of the anterior chamber and the refractive error. In regard to the variations in the refractive power of the lens, the total refractive power and the axial length, there are no conclusive investigations on record, and our knowledge in this respect is only approximate. The results of the earlier investigations indicate, however, with a fair degree of certainty that the axial length cannot show a normal variation. It is also known that the latter is strongly correlated to the refractive error.

The purpose of this treatise is to examine the variation of the in-

dividual optical elements and the covariation between them. The investigation comprises 1,000 individuals (315 women and 685 men) between 20 and 35 years of age, and for the right eye the following quantities have been determined:

1. Refractive error, according to Donders.
2. Curvature of the anterior surface of the cornea, by means of Javal-Schiotz's ophthalmometer.
3. Depth of anterior chamber, according to Lindstedt.
4. Length of the internal axis, according to Rushton.

On the basis of the data thus obtained calculations have been made of the refracting power of the lens (viz., the refracting power measured from the anterior vertex) and the total refracting power of the eye. In this way the chief characteristics of the optical system of the eye have been determined. The calculations are based exclusively on the values of the horizontal section. The main results of the statistical treatment are as follows:

A. Concerning the variation of the individual elements.

The elements of the refracting system (refracting power of the cornea, refracting power of the lens, depth of the anterior chamber), and the total refracting power all show a variation which does not noticeably diverge from the normal. The variation of the axial length, on the other hand, shows pronounced divergences from the normal line, partly in the form of a rather considerable positive skewness, partly in the form of a pronounced leptokurtosis. The characteristics brought out from the entire material are shown in Table 29.

TABLE 29

Elements	Arithmetic Mean	Dispersion		
Radius of cornea	7.86±0.008	±0.26±0.006		
Depth of anterior chamber	3.68±0.009	±0.29±0.006		
Axial length	24.00±0.035	±1.09±0.024	+0.81±0.077	+3.35±0.154
Refracting power of cornea	42.84±0.044	±1.40±0.031		
Refracting power of lens*	17.35±0.044	±1.48±0.031		
Total refracting power of the eye*	58.13±0.056	±1.78±0.040		

*It is necessary again to emphasize that what is referred to here is the refracting power measured from the anterior vertex and that the value noted for this reason is approximately 3 diopters less than that which is ordinarily given. For the same reason the value of the total refracting power here given is about 1.5 diopters less than the real value.

For the female material the averages are approximately 1.5 per cent lower than for the male.

B. Concerning the covariation of the elements.

The correlations existing between the dioptric elements are slight. the result of which is that the total refractive power shows a somewhat lesser dispersion than would be the case if the optical elements varied independently of each other.

The total refracting power shows a moderate correlation to the convergence of the axial length ($r_{DB1} = +0.61 \pm 0.020$), which is a mark of the great frequency of cases of low refractive error.

C. Concerning the variation of the optical elements in relation to the total refracting power.

The dioptric elements show no correlation whatever, or at the most only a very slight correlation to the refractive error. It is most pronounced in the case of the anterior chamber ($r_{Ad} = -0.34 \pm 0.028$), whereas the refracting power of the lens varies entirely independently of the refractive error. Nor is there any indisputable evidence of correlation to the refractive error in the total refracting power. In regard to the axial length the case is wholly different. This shows a pronounced correlation with the refractive error amounting to $r_{Ab1} = 0.76 \pm 0.014$. This, then, confirms the conception that the axial length is the most important of those quantities determining the refractive error.

The most important correlation coefficients are shown in Table 30.

TABLE 30

Summary of the total correlation coefficients.

Elements	A		d	b_1	D_1	D_2	D
A	.....						
σ	.....	.....					
d	—0.34 ±0.028	—0.10 ±0.031	.....				
b_1	—0.76 ±0.014	+0.31 ±0.029	+0.44 ±0.026	.....			
D_1	—0.18 ±0.031	.....	.....	.....	.....		
D_2	—0.00 ±0.031	.....	.....	—0.36 ±0.028	—0.12 ±0.031	.....	
D	—0.10 ±0.031	.....	.....	—0.54 ±0.022	+0.66 ±0.018	+0.70 ±0.016	
$1/b_1$	.....	.....	.....	.....	.....	.....	+0.61 ±0.020

The skewness and the relatively great frequency of extreme variables in the distribution of the refractive error appear to be wholly explained by corresponding characteristics in the distribution of the axial length. This is of such a nature that one must suppose that the material is made up of several biologically different groups with

mutually different conditions of variation. The exact demarcations between and characteristics of these groups cannot be determined on the basis of the present investigation. The division made by earlier writers into conus eyes and conusless eyes does not explain the abnormal variation of the axial length, as neither of these groups shows a normal variation with respect to the internal axis.

BIBLIOGRAPHY

I. Experimental Techniques and Statistical Methods

Aitken. Statistical Mathematics. Edinburgh 1944.
Arley o. Buch. Sandsynlighedsregning o. s. w. København 1940.
Barlow's Tables of squares, cubes, etc. London 1941.
Berg. (a) Undersökningar över främre hornhinneytans form. Göteborg 1929.
Brandes u. Dorn. Ann. d. Physik u. Chemie 60:478, 1891.
Charlier. Vorlesungen über die Grundzüge der mathematischen Statistik. Hamburg 1920.
Dahlberg. Statistical Methods. London 1940.
Fisher. Statistical Methods for Research Workers. 1944.
Gifford and Barth. Arch. of Ophth. N.s. 11:81, 1934.
Giljam. Lärobok i nomografi. Stockholm 1943.
Goodwin. Elements of the precision of measurements. 1920.
Gullstrand. Einführung in die Methoden der Dioptrik des Auges des Menschen. Handb. der physiol. Method. Leipzig 1911.
Helmholtz. Hd. d. physiolog. Optik Bd. 1, 1909.
Himstedt und Nagel. Ann. d. Physik u. Chemie 4:537, 1901.
Holm. Les états de la réfraction oculaire chez les Palénégrides etc. Lund 1937.
Kemp. Statistiske Metoder i Medicin og Biologi. København 1942.
Koller. Graphische Tafelin z. Beurteil. stat. Zahlen. 1943.
Lindstedt. Om mätning av fr. ögonkammarens djup. 1913.
Nordenson. (a) Ophthalmometrie. Handbuch der ges. Augenheilk. Bd. III. Berlin 1925.
Pirie. Canad. M.A.J. 27:488, 1932.
Rosengren. (a) Acta ophthalm. 15:501, 1937.
Rushton. Trans. Opht. Soc. U.K. 58:136, 1938.
Röntgen. Sitz. d. K. Preuss. Akademie d. Wissensch. s. 591, 1897.
Schiötz. Norsk Mag. f. Laegevetensk. n:r 2. 1913.
Stenström. Nord. Medicin 24:2037, 1944.
Taft. Am. J. Roentgenol. 28:245, 1932.
Tscherning. Optique Physiologique. Paris 1898.
Yule and Kendall. An introduction to the Theory of Statistics. London 1945.
Wicksell. Elementen av Statistikens tenori. Lund 1920.

II. Other References

Adamük und Woinow. Arch. f. Ophth. 16:144, 1870.
Awerbach. Zit. Michel-Nagel Jahresber. d. Ophth. 31:652, 1900.
Barrington and Pearson. Eugenic labor. memoirs V. London 1909.
Berg. (b) Arch. f. Ophth. 127:606, 1931.
Betsch. Klin. Monatsbl. f. Augenh. 82:365, 1929.
Bourgeois et Tscherning. Ann. d'ocul. 96:203, 1886.
Crzellitzer. Fortschr. a. d. Geb. d. Röntgenstr. 5:245, 1901.
Czellitzer. Klin. Monatsbl. f. Augenh. 19:301, 1927.
Dalén. Mitt. a. d. Augenklin. d. Carol Inst. 8:45. Sthlm 1906.
Donders. Die Anomalien der Refraktion und Akkomodation des Auges. Wien 1866.
Eisler. Kurzes Hb. d. Ophthalmologie. Bd. 1:24, 1930.
Erggelet. Die Refraktion u.s.w. Kurzes Hb. d. Ophthalmologie Bd. 2:460, 1932.
—— und Geserick. Ber. ü. d. Versamml. d. dutsch. ophth. Gesellsch. 51, 1936. Zentralbl. f. d. ges. Ophth 31:340, 1936.
Freytag. Vergleich. Untersuchungen über die Brechungsindices der Linse u.s.w. Wiesbaden 1907.
Gallus. (a) Klin. Monatsbl. f. Augenh. 44:398, 1906.
—— (b) Klin. Montasbl. f. Augenheilk. 73:491, 1924.

Goldmann und Hagen. Ophtalmologica 104:15, 1942.
Hallauer. Ber. ü. d. Versamml. d. deutsch. ophth. Gesellsch. 39:113, 1913.
Heine. (a) Arch. f. Augenh. 38:277, 1899
—— (b) Arch. f. Augenh. 40:160, 1900.
Helmholtz. Arch. f. Ophth. 1; 2:1, 1855.
Hess. Graefe-Saemisch. Hb. d. ges. Augenheilk. Bd. 12, 1910.
Knapp. Arch. f. Ophth. 6; 2:1, 1860.
Kronfeld and Dewney. Arch. f. Ophth. 126:487, 1931.
Leber. Ber. ü. d. Versamml. d. deutsch. ophth. Gesellsch. 33:203, 1906.
Leibowicz. Ztschr. f. ophth. Optik 16:33, 1928.
Mandelstamm und Schöler. Arch. f. Ophth. 18:155, 1872.
Marschke. Klin. Monatsbl. f. Augenh. 39:705, 1901.
Nordenson. (b) Nord. Med. Arch. 47:12, 1914.
Paul. (a) Ber. ü. d. Versamml. d. deutsch. ophth. Gesellsch. 51, 1936: Zentralbl. f.d.ges. Ophth. 36:310, 1936.
—— (b) Arch. f. Ophth. 138:55, 1937.
Raeder. Arch. f. Ophth. 110:73, 1922.
Randall. Ber. ü. d. 7. per. intern. ophth. Congr. Heidelberg: 511, 1888.
Rieger. Arch. f. Ophth. 144:470, 1941.
Rosengren. (b) Acta ophth. 8:99, 1930.
—— (c) Acta Ophth. 10:253, 1932.
Rosow. Arch. f. Ophth. 11; 2:129, 1865.
Scheerer. (a) Klin. Monatsbl. f. Augenh. 82:511, 1929.
—— (b) Ber. ü. d. Versamml. d. deutsch. ophth. Gesellsch. 47:118, 1928.
Schnabel und Herrnheiser. Ztschr. f. Heilk. 16:1, 1895.
Sorsby and O'Connor. Nature 156:779, 1945.
Stadfeldt. Den mennesk. Linses optiske Konstanter. Kjøbenhavn 1898.
Steiger. (a) Beiträge zur Physiologie und Pathologie der Hornhautrefraktion. Wiesbaden 1895.
—— (b) Ztsch. f. Augenheilk. 20:97, 1908.
—— (c) Die Entstehung der sphärischen Refraktionen des menschlichen Auges. Berlin 1913.
Straub. Ztschr. f. Psychol. u. Physiol. d. Sinnesorg. 25:78, 1901.
Strömberg. Acta. Ophth. 14:281, 1936.
Tron. (a) Arch. f. Ophth. 122:1, 1929.
—— (b) Arch. f. Ophth. 124:544, 1930.
—— (c) Arch. Oftalm. 7:441, 1930. Zit. Zentralbl. f. d. ges. Ophth. 25:38, 1931.
—— (d) Arch. f. Ophth. 126:454, 1931.
—— (e) Arch. f. Ophth. 132:182, 1934.
—— (f) Vestn. Oftalm. 15:190, 1939. Zit. Zentralbl. f. d. ges. Ophth. 45:340, 1940.
Waardenburg. Klin. Monatsbl. f. Augenheilk. 79:169, 1930.
Wibaut. (a) Arch. f. Ophth. 116:596, 1926.
—— (b) Klin. Monatsbl. f. Augenh. 82:684, 1929.
—— (c) Biologisch-statistische Refraktionsuntersuchungen. München 1932.
Zeeman. Arch. f. Ophth. 78:93, 1911.

ABSTRACTS

SOME THOUGHTS ON VISUAL TRAINING. E. C. Scott. Optometric Weekly, 38. 15. 539-540, 1947.

The author believes: (1) That 50 per cent of all ametropic patients require some type of visual training to supplement the glasses which are prescribed. (2) That there is a need for a large group of optometric specialists with graduate training in orthoptics. (3) That all optometrists should not engage in orthoptic training but rather refer these cases to those whose interest lies in this work and who have had the specialized training and equipment the work requires, and (4) that the orthoptic training work now done is by no means the best which can be done. In this the author points out that in the future patients will receive greater good from orthoptic training periods as research work is extended into this specialized field. V. H.

AMERICAN JOURNAL OF OPTOMETRY
and ARCHIVES *of*
AMERICAN ACADEMY OF OPTOMETRY
Established 1924

Vol. 25 OCTOBER, 1948 No. 10

EDITORS AND STAFF

Dr. Carel C. Koch . . . . . *Editor*
Dr. Robert E. Bannon . . . . . *Research Editor*
Virginia Huck . . . . . *Editorial Assistant*
Harry Brookins . . . . . *Advertising and Production Manager*
Mary L. Kerr . . . . . *Circulation Manager*

Publication and Academy Office: 1502 Foshay Tower, 821 Marquette Ave.
Minneapolis 2, Minnesota

Annual Subscription, $5.00 in Advance; Canada, $5.50; Foreign, $6.00;
Single Copies, 50c.

Original papers, scientific communications, clinical reports, books for review, and correspondence should be sent to the editor. Subscriptions and applications for single copies should be addressed to the circulation manager. Copy of advertisements must be sent in by the first of the month preceding their appearance. Communications with reference to advertising or other journal business should be addressed to the advertising manager. Academy correspondence should be addressed to Dr. Carel C. Koch, Secretary of the American Academy of Optometry.

Published Monthly by the
AMERICAN JOURNAL OF OPTOMETRY PUBLISHING ASSOCIATION

The American Academy of Optometry and the publishers of this journal have no objection to the reprinting by other magazines of any of the articles in this issue, provided such reprints are properly credited to the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

ON THE RETENTION OF FREE ENTERPRISE

During the past few months, we have willy-nilly, been floundering about in a bog of political bunkum which historically precedes every presidential election. In the effort to secure votes, political platforms are drafted and candidates air their views on every conceivable subject. Government spending has been criticized. Organized business has been widely attacked, largely because recent corporate profits have been good. Agriculture has had its full share of blame because food prices have been high and the farmer has enjoyed fair prices for his products. Labor is criticized because of high wage demands. The health worker, too, has come in for his share of censure. We are told that health costs are too high. President Truman, Governor Warren, Senator Taft and others are demanding the Congress legislate the country into vague forms of socialized health programs of major size.

If citizens generally took this political talk seriously their inescapable reaction would be that to make profit on one's labor or business ability or professional skill is all wrong, and that the only "righteous" among us are those who fail to make a profit. This idea, of course, would be nonsense. Actually, the profit motive has not been under attack, except perhaps in some extreme left-wing circles.

The talk we hear on every hand is just the exuberant mouthings of vote-seeking politicians who hope to secure the approval of those disgruntled by the current inevitable postwar inflation. This talk will subside rapidly after the November election. This is one of the unique phenomenon of a democracy and we would not have it otherwise.

However, this type of loose talk does have its drawbacks. The windy generalities engaged in by politicians are at times believed by the unsuspecting and when repeated often enough become part of the political folk lore of the country.

This is true of a great portion of the discussion which rages around the health of the American people. One favorite trick of the politicians is to drag out the health statistics (sic) compiled by the draft boards during World War II. Another is to refer to the number of counties which lack complete hospital facilities. At the same time, however, they fail to take into account the fact that a large number of counties would have too few patients to keep a hospital staff busy, or are so located as to be adjacent to existing adequate hospital care across a county line.

Were the country in the depths of a depression one might expect talk of socialized health care. Today, however, employment at excellent wage levels is at the highest point in American history. The national income is well over 200 billion and individual incomes are at their highest average level. People generally have the means to secure required health services and have been doing so.

Local health agencies serving the indigent are already in the field to care for those who cannot secure this service in the usual manner. In general, these agencies are doing a good job which should be expanded and strengthened.

During this election period there has been no evidence presented which indicates an immediate need for an across-the-board program of socialized health care. In fact, the need seemed greater several years ago than today. Yet at this time politicians are entertaining the electorate with their doubtful views on health care.

As the writer pointed out several years ago, the need does exist for specialized programs to assist the indigent and those in the lowest income brackets.[1] This type of aid can be supplied by special supple-

1. Koch, Carel C. Possible Effects of Public Health Programs Upon Optometry. Am. J. Optom. & Arch. Am. Acad. Optom. 22.3. 135-139. 1945.

mentary grants to existing agencies in the effort to enable them to more adequately cover the field of health care for the underprivileged. This can be done without socializing all health care and without removing the incentive to progress which exists under our system of free enterprise.

Professional health workers should now start the machinery to secure such needed congressional grants as to fully meet the health requirements of the indigent. The administration of the programs should remain at the local level. The work should be done by existing practitioners in their offices along with their regular practice.[2]

Optometry working with organized medicine should also throw its weight against all programs of complete socialized health care. At this time we must be prepared to defeat such unsound proposed legislation as is engendered by the pre-election oratory. CAREL C. KOCH

"OPTOMETRY" BY HOFSTETTER

Hofstetter has given the profession a new book which merits serious attention. For a considerable period optometry has needed a text book which covered the history, scope, legal position, ethics and undergraduate educational program of present day graduates. This new text does just this. While an enormous amount has been written on these subjects in recent years, (so much so that four of the five national optometric publications devote most of their space to these matters) the profession had no place to turn to find each subject fully and conservatively covered in a concise and authentic manner.

Hofstetter is well known in optometry as a teacher and writer. His work at the School of Optometry, The Ohio State University, has helped make that educational center one of the outstanding in the profession. His periodic technical writings have been eagerly followed by thousands of optometrists because of his clear and thorough covering of the subjects he has investigated. His new book follows the same meticulous pattern.

In addition to the background material already mentioned, optometrists will find in "Optometry" a review of types of practice, professional fees, earnings, patient relationships, malpractice and a chapter on the optometrist as an expert witness. Here, too, the material presented is factual and up to date. The author engages in no wishful thinking but presents optometry to his readers as it is today, and points out the possible courses for the profession to follow in the future.

---

2. Koch, Carel C. A Plan for Refractive Eye Care for the Indigent and the Medically Indigent in Minnesota. Am. J. Optom. & Arch. Am. Acad. Optom. 19.8. 319-335, and 19.9. 359-377. 1942.

Optometrists everywhere will benefit by reading this book. Not only will they enjoy its style and subject matter but they will receive encouragement in their work as they note the progress which has been made in recent years in this health speciality. In addition, they will find numerous suggestions which, if put in force, will make them better and more prosperous optometrists. Also they may study some of their shortcomings and thus lay plans to eliminate these.

That the book should enjoy wide reading among optometrists goes without saying. In addition, the book should be made available to the public and to members of other professions. Here state and local optometric groups have an important job to do. Copies of "Optometry" should be presented to public libraries for their reference and vocational guidance departments. Optometrists should also present copies to the libraries of nearby general colleges and universities, and to the vocational placement faculty committee at the local high school level.

Hofstetter's new book "Optometry"[1] adds another worthwhile chapter to the development of professional optometric practice.

CAREL C. KOCH

TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

NEW ACADEMY MEMBERS

The Academy welcomes the following new members to Fellowship:

Dr. Edwin D. J. Fletcher, 1616½ North Vista Street, Hollywood, California.

Mr. Sylvester K. Guth, Nela Park, East Cleveland, Ohio.

Dr. George W. Knox, School of Optometry, The Ohio State University, Columbus, Ohio.

Dr. Alvah H. Lauer, Director, Driving Research Laboratory, Iowa State College, Ames, Iowa.

Dr. Helen M. Robinson, Director, University of Chicago Reading Clinics, Graduate Education Building, Chicago, Illinois.

Dr. J. Maurice Wareham, Dowds-Rudin Building, Mount Vernon, Ohio.

Dr. Claude A. Warner, 315 Baltimore Life Building, Baltimore, Maryland.

1. Hofstetter, Henry W. Optometry, Professional, Economic and Legal Aspects. Published by the C. V. Mosby Company, 3207 Washington Blvd., St. Louis, Mo. 412 pages. Illustrated. Cloth, $6.50. 1948.

ANNUAL ACADEMY CONVENTION

REMINDERS

The time: December 4, 5, 6, and 7. The place: Hotel Robert E. Lee, Winston-Salem, North Carolina. Banquet dress: Formal.

PROGRAM

Dr. F. M. Foote, Executive Director of the National Society for the Prevention of Blindness will be the speaker at the formal annual round table dinner. The following program of papers has been planned by Dr. Harold Simmerman, assisted by Drs. Julius Neumueller, Philadelphia, Henry Hofstetter, The Ohio State University, John D. Perry, Winston-Salem, and Arthur R. Neale, Patterson, New Jersey:

PROGRAM OF ANNUAL MEETING OF ACADEMY
WINSTON-SALEM, NORTH CAROLINA

Saturday, December 4, 1948

Time

9:00-10:00 A. M. ..... Registration

10:00-12:00 ..... Business Session
Reports by officers and committee chairmen.

1:30 P. M. ..... Section Meetings
Aniseikonia, Contact Lenses, Orthoptics.

3:00 P. M. ..... Lecture
"An Experimental Analysis of Properties of Visual Acuity Test Objects," Glenn Fry, Ph.D., The Ohio State University, Columbus, Ohio.

3:30 P. M. ..... Lecture
"Correcting Lens—Form and Thickness Considerations for Various Near Points," Frederick W. Sinn, O.D., Pennsylvania State College of Optometry, Philadelphia, Pennsylvania.

4:00 P. M. ..... Lecture
"An Experiment in Retinal Imagery," James H. Grout, O.D., Northern Illinois College of Optometry, Chicago, Illinois.

5:10 P. M. ..... Barbeque Dinner
Sponsored by North Carolina Chapter.

8:00 P. M. ..... Lecture
"The Role of Orthoptics in Anomalies of Reading and Learning." William Smith, O.D., Boston, Massachusetts.

Sunday, December 5, 1948

10:00 A. M. ..... Lecture
"A Binocular Balance Test," Meredith W. Morgan, Jr., Ph. D., School of Optometry, University of California, Berkeley, California.

11:00 A. M. ..... Lecture
"A Survey of Practices in Prescribing Presbyopic Adds," H. W. Hofstetter, Ph.D., School of Optometry, The Ohio State University, Columbus, Ohio.

11:30 A. M. ..... Lecture
"Psychosomatic Optometry" (Subnormal Vision), I. Irving Vics, O.S., Albany, New York.

Noon ..... Lunch
(Special luncheon for chapter officers and executive council.)

1:30 P. M. ..... Section Meetings

3:00 P. M. . . . . Lecture
"A Study of 3,000 Static Skiascope Readings on School Children," and "A Study of Relationship of Intelligence Testing to Refractive State," Monroe J. Hirsch, Ph.D., School of Optometry, The Ohio State University, Columbus, Ohio.

4:00 P. M. . . . . Lecture
"A Sensitometric Method of Refraction—Theory and Practice," Matthew Luckiesh, D.Sc., and Sylvester K. Guth, Lamp Department, General Electric Company, Cleveland, Ohio.

7:00 P. M. . . . . Lecture
"Studies of Fusional Movements," V. J. Ellerbrock, Ph.D., School of Optometry, The Ohio State University, Columbus, Ohio.

Monday, December 6, 1948

9:30 A. M. . . . . Lecture
"Haploscopic Measurement of Relationship of Accommodation and Convergence Over Extended Periods," Mathew Alpern, O.D., The Cleveland Contact Lens Center, Ltd., Cleveland, Ohio.

9:45 A. M. . . . . Lecture
"Concerning Ways of Understanding Vision," S. Howard Bartley, Ph.D., Michigan State College, East Lansing, Michigan.

10:00 A. M. . . . . Lecture
"Readiness and Emotional Problems Associated with Reading Disabilities," Wilmot F. Schneider, M.D., Shaker Heights, Ohio.

11:00 A. M. . . . . Lecture
"An Analysis of Keratometric Findings." Donald Kratz, O.D., and William G. Walton, Jr., O.D., Pennsylvania State College of Optometry, Philadelphia, Pennsylvania.

1:30 P. M. . . . . Section Meetings

3:00 P. M. . . . . Business Session
Election of Officers.

7:00 P. M. . . . . Annual Formal Banquet
Speaker, Dr. F. M. Foote, Executive Director, National Society for the Prevention of Blindness.

Tuesday, December 7, 1948

9:30 A. M.—Drs. Eugene Freeman, Robert Graham, Henry B. Day, Jr., and Richard Tousey will present papers. Titles to be announced later.

1:30 P. M. . . . . Section Meetings

ABSTRACTS

READING CORRECTION IN HIGH MYOPIA, London Refraction Hospital Clinical Report, The Optician, (London), 113, March 28, p. 146-147, 1947.

Patient, age 68, complained of poor distance vision and inability to do close work except by removing her correction and reading at a distance of a few centimeters with her left eye only. She was wearing,

O.D. —22.00 D. Sph. V.A. 6/60—.
O.S. —20.00 D. Sph ⊃ —4.00 D. Cyl. axis 30. V.A. 6/60.

This correction had been in use for 7 years. Ophthalmoscopy revealed large areas of choroidal atrophy in both eyes as well as the typical fundus and vitreous changes associated with high myopia. There was no retinal detachment.

A refraction disclosed the following findings,

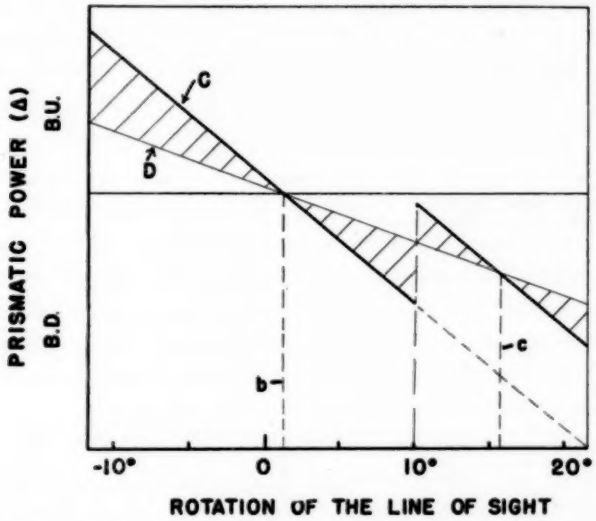
O.D. —23.00 D. Sph. V.A. 3/36.
O.S. —20.00 D. Sph. V.A. 6/24.

Add O.U. + 5.00 D. Sph ⊃ 4Δ base-in. Near Point V.A.J2. The foregoing correction for near enabled the patient to read at 20 cm., and while the left eye did most of the work the right eye was giving support. C. C. K.

ERRATA

In a paper published in this journal (July, 1948) entitled "A Clinical Evaluation of Compensation for Prismatic Imbalances," a figure was used for schematic illustration of the prismatic effects of a pair of compensated anisometropic lenses with rotation of the lines of sight. It has been pointed out by Dr. M. J. Allen that the curve representing the prismatic effects through the slab-off portion of one lens is incorrect. The drawing, modified in accordance with the correction, is reproduced below.

VINCENT J. ELLERBROCK



Schematic illustration of the prismatic effects of a pair of compensated anisometropic lenses with rotation of the lines of sight. Curve C represents the prism power of one lens while D represents the prism power of the other. The shaded area between the two curves indicates the prismatic imbalance.

CURRENT COMMENTS

Virginia Huck
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department; such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

DR. BOEDER LECTURES ABROAD

Dr. Paul Boeder, director of American Optical Company's Bureau of Visual Science, recently returned from abroad where he lectured in England and Germany.

During his stay in London he attended the Scientific Information Conference of the Royal Society, and, at the invitation of the Worship-

ful Company of Spectacle Makers and Mr. W. E. Hardy, editor of the *Optician*, spoke before a group of people distinguished in various fields of ophthalmic science. In his lecture, Dr. Boeder discussed the theory of space perception, emphasizing the important contributions recently made by Dr. R. K. Luneberg in establishing the metric of the visual space. At the conclusion of the lecture, Lord Charnwood of London led a discussion.

Both Lord Charnwood and Mr. Hardy recently completed tours of the United States, during which time they visited optical companies, optometrists, optometric editors, and attended visual conferences.

While in London, Dr. Boeder also visited ophthalmic educational institutions and general ophthalmic hospitals and orthoptic clinics.

In Goettingen, Germany, he spoke on the mathematical aspects of space perception before an audience of mathematicians, physicists and psychologists.

SOUNDS LIKE INFLATION

We'd like to have been there to get a glimpse of a $15,000.00 pair of glasses. Where? At a recent fashion show in New York. We did receive an invitation: "Tura, Inc., requests the honour of your presence at the preview showing of 'Fashions in Glasses.' Provocative Specs from $12.50 to $15,000.00 . . . the first fashion show, open to the public, dedicated exclusively to women who wear glasses."

Some critics would say that's overdoing things a bit, but personally we feel the American optometrist should be grateful someone puts a little joy into spectacle wearing so that women will wear much-needed corrections. Many a woman has remarked to this writer that she wouldn't wear her glasses (even if she failed to recognize friends on the street) if the frames weren't so attractive. The fact that frames are an added colorful accessory is incentive to wearing the correction, they agree.

CENTRAL COAST OPTOMETRISTS HOLD ANNUAL WORKSHOP

San Jose, California, was host to the fourth annual Visual Training Workshop sponsored by the Central Coast Optometric Association in August.

Dr. Thaddeus R. Murroughs, Linton, Indiana, national chairman of the committee on visual training of the A. O. A., was the key speaker. Dr. Murroughs spoke on "The Organismic Approach to Visual Training," the first day, and "Consideration of Training Procedures," the second day.

Over 100 optometrists and their assistants participated in the classes and clinical demonstrations at the two-day session.

OPTICAL STREAMLINING

Victory Optical Company is streamlining the streamlined. On October 1, the firm announced a new frame, the *Honey Bee*, which is a new version of the *Honey* frame.

The Kono Manufacturing Company is streamlining its plant facilities. Officials of the company announced recently that construction on a new factory has begun and the building should be completed by the end of this year. The new plant will double the capacity of their Long Island main plant.

LOS ANGELES COLLEGE OCCUPIES NEW HOME

Classes convened in the new quarters of the Los Angeles School of Optometry for the first time on September 20. On September 19, the Alumni Association was host to school officials, faculty and friends of the school in celebration of the opening. The new structure, a two-story quadrangle of cream and brown stucco, was recently donated by the War Assets Administration and in the words of Dean Ernest Hutchinson is "replete with every facility of an approved professional school." The college has been occupying temporary quarters since 1933.

Dean Hutchinson reports the adoption of an expanded curriculum for students entering fall quarter which includes two years of pre-optometry subjects followed by three years of professional studies.

SOUTHERN COLLEGE GRADUATES SIXTY-FOUR

Sixty-four students received Doctor of Optometry degrees at Southern College of Optometry on September 17. In keeping with past tradition, commencement exercises were held in the Cadet Room of the Peabody Hotel, in Memphis, Tennessee.

PENN STATE CONFERS NINETY DEGREES

Charles A. Ford, Dean of Temple University's new Community College and Technical Institute gave the commencement address at Pennsylvania State College of Optometry on August 26. Doctor of Optometry degrees were conferred on 90 candidates.

Dr. Ford also presented two gold medals on behalf of the Distinguished Service Foundation of Optometry, one to Onofrey G. Rybachok, faculty member, for his contributions to optometry as an anatomist, and the second to Dr. Edwin Silver, of Washington, D. C., for his outstanding work as chairman of the Motorists' Vision committee. Representing the D.S.F.O. were Dr. Clinton Padelford, Fall River, Massachusetts, president, and Dr. Laurence Folsom, South Royalton, Vermont, secretary.

SYNTONIC GROUP MEETS AT KANSAS CITY

The College of Syntonic Optometry elected the following officers

at its annual assembly at Kansas City, Missouri, on September 6th: Dr. H. W. Hagenah, Kansas City, president; Dr. W. I. Davis, Tulsa, Oklahoma, vice president and director of research; Dr. E. C. Scott, Piqua, Ohio, secretary-treasurer; Dr. Herman Shurin, Kansas City, educational director. The following doctors were elected to trusteeship: Dr. Preston Kline Caye, Los Angeles, California; Dr. H. L. Leonard, Lexington, Kentucky, and Dr. R. L. Cassell, Cadiz, Ohio.

AMERICAN BOARD OF OPTICIANRY

Honorary degrees were recently awarded 23 Americans by the American Board of Opticianry, an organization founded in January, 1947 to aid in the establishment of higher educational standards for the practice of opticianry. The men so honored with certificates naming them as Founders of the American Board of Opticianry and as Honorary Masters in Opthalmic Optics are as follows:

Dr. William Benedict (M.D.), and Dr. Charles Sheard (Ph.D.), of Rochester, Minnesota; Dr. Galen Kintner (O.D.), Wabash, Indiana; Dr. Carel C. Koch (O.D.), Minneapolis, Minnesota;

Messrs. R. C. Uhlemann, H. G. Wright, A. G. Hager, Arthur Champeau, J. Earl Lewis, of Chicago, Illinois;

Messrs. P. E. Dempsey, Toledo, Ohio; Charles M. Fehr, Salt Lake City, Utah; Arthur Ehrmantraut, Miami, Florida; A. J. Jorgenson, Seattle, Washington; Norman A. McLeod, Providence, Rhode Island; A. E. Mangold, New York, New York; Russell L. Stimson, Los Angeles, California; Robert E. Lindmark, Eau Claire, Wisconsin;

Messrs. A. H. Nordland, Albert L. Anderson, Will R. Anderson, Charles L. Waldo, and Leslie Myers, of Minneapolis; and Robert S. Ramsay, Winnipeg, Manitoba, Canada.

The American Board of Opticianry is managed by a board of 15 opticians from the United States and Canada, and also an advisory educational and professional counsel consisting of representatives of optometry and ophthalmology.

Requirements for certification by the Board are as follows: After 1950, opticians to be certified must have a minimum of two years' accredited schooling in a recognized university teaching the academic subjects required by the American Board. If the student successfully passes his first examination granting him a certificate as a Junior Diplomate in Opticianry he is then eligible for a three-year fellowship in opticianry under the guidance and supervision of an accredited optician, making a total academic training of five years. At the end of the five-year educational period he is eligible to go before the American Board and take an examination that will qualify him to receive a degree as Master in Ophthalmic Optics.

Dr. Charles Sheard is president of the Board; and Mr. Leslie W. Myers, chairman of the National Executive Committee.